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TRANSACTIONS

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Edited by the Secretary, under the Direction of the Committee on Library.

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OF THE SOCIETY.—On the first and third Wednesday EVENINGS of the month, at EIGHT o'clock, as follows: February 21st, March 7th and 21st, April 4th and 18th, May 2d and 16th, June 6th and 20th, September 5th and 19th, October 3d and 17th, 1877.

OF THE BOARD OF DIRECTION.—On the first Wednesday AFTERNOONS of the month, at THREE o'clock, as follows: March 7th, April 4th, May 2d, June 6th, July 4th, August 1st, September 5th and October 3d, 1877.

NINTH ANNUAL CONVENTION, at New Orleans, April 24th, 25th and 26th, 1877.

TWENTY-FIFTH ANNUAL MEETING, November 7th, 1877, at 10 o'clock, A.M.

ROOMS, 4 EAST TWENTY-THIRD STREET (SOUTH EAST CORNER OF BROADWAY), NEW YORK.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INCORPORATED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CXXXV.

A MEMOIR OF AMERICAN ENGINEERING.

A Paper by JOHN B. JERVIS, C. E., Honorary Member of the Society.

Read October 18th, 1876.

To the American Society of Civil Engineers:

I have had under consideration, your request to furnish such history of American engineering as could be gathered from my observation and experience. At my age, now past fourscore years, I cannot undertake the labor of looking up documents, so as to be exact in facts, and can only give them approximately as to dates. I necessarily feel embarrassment in undertaking this, from the fact that I have been so personally interested in much that has been done, that my statements may easily be attributed to egotism. In this regard, I hope you will be charitable, and that you will have no occasion to doubt the fidelity in anything I may say.

THE ERIE CANAL.—My first experience was on the original construction of the Erie canal, between Buffalo and Albany, in the State of New York. This work was commenced and ground broken, July, 1817. As the circumstances under which I first entered on this department of work may be interesting, I will occupy a few lines in describing it.

The work had been commenced in the town in which I resided, but the line had not yet been located through a piece of cedar swamp in this vicinity. Hon. Benjamin Wright, the Chief Engineer, resided in the same village—Rome, N. Y. A party of engineers came on to make this

location, but they had no axemen, a portion of the force indispensable for this service. Being well acquainted with my father, Mr. Wright called on him to supply two axemen for this service. My father inquired of me if I would take one of his axemen and do the work. I was then, (1817), near twenty-two years of age, and as the work was expected to take only a few days, I cheerfully assented to go. Mr. N. S. Roberts was the engineer who had charge of the party, a pretty stern sort of a man, and very exacting. Myself and assistant were expert axemen, and with the enthusiasm of a new and untried operation, we entered on the work. It was soon evident our principal was pleased with the manner we executed our duty. My attention was soon directed to the use of the instruments, which at first appeared quite mysterious. In the course of proceeding, it often happened that I was brought to wait a little time with the rodman (as he was called), or target-bearer. At such times, I was led to examine the target and notice the operations. In a day or two, I began to think I could do that duty, and so thoughts rambled in my mind, of learning the art. But then I thought, I had nothing but a common school education, and how should I be able to master the mysteries of such a science as engineering appeared to be? Still I pondered on the subject, and so far concluded, that what others could do, I could do. At the last day of this service, while the party was taking its lunch in a little huddle in the swamp, I ventured, half jest and half earnest, to ask the principal, "What will you give me to go with you, next year" (this was in November), "and carry one of those rods?" To this, he replied that he would give me $12 per month. This was so prompt that I was a little startled, and began to think very seriously of the matter.

So, you see, I began my experience in engineering as an axeman, and having so well acquitted my duty in this, that it was thought I might succeed in a higher service. With some trepidation, this engagement was settled, and I occupied such evenings and other times as my daily avocations permitted, in the study of surveying, the art at that time regarded as the basis of civil engineering; and on April 10th, 1818, I started from Rome with a locating party consisting of about twelve persons. All but the principal of the party, Mr. Roberts, set off on foot, having a wagon for our baggage and tents. The third day, after a very muddy walk, we reached Geddes, near Syracuse, and pitched our tents. Early in July, we completed the location to the Seneca river, at Montezuma. I was now a regular rodman of three months' experience. The party returned to Rome and was disbanded.

There had been now, a large portion of the middle division, (Utica to Montezuma) put under contract, and several small parties, each with a Resident Engineer, was organized to direct the execution of the work. I was assigned to a party having about 17 miles in charge, in the counties of Madison and Onondaga, under Mr. David S. Bates. The only qualification of my principal was, that he was a land surveyor, of good standing. As my experience in handling levelling instruments was greater than his, he very readily allowed me to run his levels. I do not mention this to his disparagement, but to show the limited range of engineering experience at that time. At the close of the season for work on the canal, I was sent to the quarry to weigh lock-stone for the winter. The next season (1819), my principal was charged with more extended duties, and I was made Resident Engineer of his division, at a salary of $1.25 per day, and $0.50 for expenses. This I regarded as satisfactory progress, though I was employed only about nine months of the year.

When this canal was constructed, the State of New York contained about 1 250 000 people. A large part of the State was a wilderness, and the surplus earnings of its citizens were mostly absorbed in clearing the forest, draining the land, and in the erection of necessary houses, offices, mills, and other improvements imperatively called for by a people settling a new country. Of course the financial question was one of profound importance, and to a large portion of the people appeared insuperable. I well remember the alarm of intelligent men, that it would sink the State in irretrievable ruin. But little had been done in such works in this country at that time. The State sought the aid of the general government. One of the Commissioners, Mr. Joshua Foreman, of Onondaga, said to me, that after they had represented at Washington their plan, and made request for aid, Mr. Jefferson said to him—"We are trying to make a canal 3 miles long at this city, and we have not been able to obtain sufficient funds from individuals, the State government and the general government to complete it, and now you ask us to aid you in building a canal 300 miles long through a wilderness. Preposterous!" Failing to obtain aid from other States, or the general government, the State of New York entered single-handed on both these great works, the Erie and Champlain Canals. The financial question, at that time a very serious one, called the attention of the best financiers of the State to its consideration. In this they devised a system, and carried it out with such fiducial integrity that the State received a premium on the 5 per cent. bonds, of 15 per cent.

I well recollect that, among the items of criticism at that day, the question of the skill of the engineer to establish long levels, and as the Rome summit here was 60 miles long, it was confidently predicted that in this case there would be failure. The level was carefully tested by Mr. Canvass White, the Principal Assistant Engineer, and such errors as were found were corrected. When the water was let in, the level proved to be correct. I may remark that, however well the science of levelling is understood, it requires great care to establish a water-level for 60 miles. Previous to this time, some small canals had been made—as the Middlesex in Massachusetts, and some others—to pass falls or rapids in natural navigation. In the State of New York, the Inland Navigation Company constructed, about the year 1798, a canal at the Little Falls of the Mohawk, of about 1 mile in length, with 5 locks, and a canal of 2 miles at Rome, to connect the Mohawk and Wood Creek, and some other improvements by locks and dams. By these improvements the batteau boats, of a capacity of 10 to 15 tons, were able to navigate the natural waters.

Hon. Benjamin Wright, of Rome, N. Y., had been an eminent land surveyor, and with Hon. James Geddes, of Onondaga, and Mr. John Broadhead, of Utica, had made the previous year, (1816) a preliminary survey and estimate of the Erie Canal, and with Mr. G. Lewis Garin, for the Champlain Canal. With the information furnished by these engineers, the State entered on the construction of the work. Mr. Wright was appointed Chief Engineer of the Erie Canal, and Mr. Geddes of the Champlain Canal.

Mr. Wright had Mr. Canvass White as his Principal Assistant, and to him was committed the duty of preparing plans for the mechanical structures. I do not think Mr. Wright made any plans of importance; though he did not draw plans, he was a very sagacious critic of any presented. He excelled in practical judgment. His Principal Assistant delighted in plodding over plans and methods of construction. He prepared the plan for locks, which, considering the times, was highly creditable to his engineering skill.* Mr. White did a very valuable service in discovering the material for hydraulic cement. I have always regarded him as having had the most strict engineering mind of any of his time. The Chief and his Principal Assistant worked remarkably harmonious together, and performed a better service to the canal than either would

* An old and near worn out copy of this lock plan I have preserved; it will be found in the folio of plans of the Delaware & Hudson Canal, now in the Society's rooms.

have done alone. As indicating the temper of the times, I notice, the Chief Engineer called on a carpenter, a Mr. Cady, of Chittenango, to prepare a plan for the wooden trunks of aqueducts. Mr. Cady's plan was adopted, and it will bear the test at this day for that kind of structure.

The Middle Section was essentially completed, at the close of 1819. But there was found more or less deficiencies that required nearly the next season, 1820, to fit it for regular navigation. The duty of attending to the further completion of this Section was intrusted to the writer, which constituted his third year's experience at no advance in salary. In the spring of 1821, I was made Resident Engineer of a Division of the Eastern Section, extending from the Nose to Amsterdam, 17 miles. This was a much more difficult duty than I had on the Middle Section. In several places the bald side hills were washed by the Mohawk river, requiring protection against its floods, and there were many more mechanical structures. This Division and the greater part of the Section between Utica and Schenectady, was completed substantially at the close of 1822. But, as was observed of the Middle Section, there were a number of items still to be done in 1822, and navigation was not opened successfully until September of that year. The work on my Division was mostly done and the accounts settled during the early winter of 1822, and in the spring of 1823, I was assigned the duty of superintending the canal for a section of 50 miles, from the Minden dam to the aqueduct across the Mohawk river. This service was one of valuable experience to me personally. Hitherto I had been *exclusively* engaged in construction, and this gave me opportunity to see the working of the canal in actual operation, and was highly interesting. It moreover gave me experience in the management of such work. The first year, I had not exclusive control, as some of my brother Residents were more or less occupied in completing their work, and I did not have full charge until the month of September. The second year I had entire charge. The Chief Engineer had left for other works, and was seldom on the canal. The Section of the canal under my charge at this time, was about one-seventh of the entire line, and more expensive to maintain than the general average. The work being new, there were frequent failures; but as weak points developed they were repaired, and the work was constantly improved. In many cases it required a good deal of activity to keep up the navigation. This Section was maintained at a cost of $600 per mile, including a large amount of work in graveling the towing-path. The work was done in a strict business way. Mr. Henry

Seymour was Canal Commissioner. He gave me full authority in regard to everything relating to the work, making an occasional visit and consulting fully on the wants of the work. There were no politics to be cared for. I selected all the foremen, and visited them all twice every week, personally directing them in regard to their work. No other part of the canal exhibited the same economy. In view of my experience in the maintenance of the canal, it appears a strange waste to see the subsequent expenditures of from three to ten times the amount.

In 1825, the canals were completed and opened for navigation by a magnificent celebration.

In March, 1825, I resigned my employment on the Erie canal. I left with the unequivocal compliment of the Canal Commissioner, Mr. Seymour; but I was ambitious to engage on new work, now being projected in many parts of the country. The success of the Erie canal, and the magnitude of its traffic, gave great impulse to canal enterprise. Mr. Wright, the Chief Engineer, had gone to the Chesapeake & Delaware and the James river canals; Mr. White to the Union and Lehigh canals in Pennsylvania, and afterwards to the Delaware & Raritan canal and the Morris canal in New Jersey, the Blackstone in Rhode Island, the Farmington in Connecticut, the Schuylkill, as also the State canals of Pennsylvania, Ohio, and other States. It is hardly necessary now to say some of these canals proved useless as commercial enterprises.

The Delaware & Hudson Canal and Railway was projected by Messrs. Wurtz, of Philadelphia. They owned coal mines in the Lackawanna valley, and entered into this project to obtain a channel for the transportation of their coal to the city of New York, and the valley of the Hudson. Under a charter obtained from Pennsylvania and New York, a company was organized in the city of New York early in March, 1825. A survey of the route, and an estimate of the cost had been made the previous year under the direction of Mr. John L. Sullivan, an engineer from Boston, and Mr. John B. Mills, as his assistant. Mr. Mills conducted the survey. The plan proposed was partly canal and partly improvement of the river by locks and dams. The cost was estimated at $1 208 000. The actual cost was nearly double this. This was a hardy enterprise for private capital, at that day, and great credit is due the enterprising Board of Directors who persevered through many difficulties to final success. Mr. Philip Howe was the first president, and was succeeded by Mr. John Bolton. The Board of Directors had engaged Mr. Benjamin Wright as Chief Engineer, who requested me to take the posi-

tion of Principal Assistant Engineer, with a view to conducting the details of administration under his general advice. I concluded the engagement March 25th, 1825, and proceeded with Mr. Mills, above referred to, to make an examination of the route. This led me to report against most of the slack-water plan, by dams and locks. The rivers were of a character that did not appear favorable, in my mind, to this kind of improvement. To my views in this report, the Chief Engineer assented, after he had examined the route, and an independent canal was decided on. The size of the canal was 4 feet depth of water, 20 feet width of bottom, and 28 feet width at top water line. The locks were 76 feet long, and 9 feet wide in the chamber, and designed for a boat of 30 tons. The total length of canal from Kingston to Honesdale is 106 miles ; it has 110 locks. From the termination of the canal at the forks of the Deyburg (Honesdale), a railroad is constructed 16 miles to the coal mines in Lackawanna valley. Intervening these, was a rise of near 900 feet to the summit of Mosaic mountain, and nearly the same descent to the mines.

At this time, no coal was brought from the anthracite coal fields, except that by arks floated down the Lehigh from Mauch Chunk, nor was the article used in New York.

The canal, commencing at Kingston on the Hudson, traversed the valley of the Rondout and Mamakating, 59 miles to the Delaware river, thence 22 miles up the Delaware to the mouth of the Lackawaxen river, and thence up the same to the forks of the Deyburg at Honesdale. The locks east of the Delaware were made of stone—the face hammered, but not cut—and laid in hydraulic cement, and the backing in quick-lime mortar. This last was a mistake. The locks on the Delaware and Lackawaxen were of dry wall masonry, faced with timber and plank. The canal was mostly completed in autumn of 1828, but not much navigation was attempted until the autumn of 1829, when the first coal was sent down.

The railroad, commencing at the mines at Carbondale, was carried to the summit of the mountain, in about 3 miles. The ascent was made by five incline planes, all but one, on an angle of one-twelfth. A less number of planes would have been chosen if the formation of the country had been favorable. The planes were operated by stationary steam engines. The cars were moved by endless chains passing round on sheave wheels, at the head and foot. In order to guard against the slipping of the chain on the upper sheave, steel studs were sunken in its groove. When

put in operation the machinery worked well, but the chain frequently broke, and had to be abandoned ; hempen rope was substituted instead. It was apprehended the rope would not have sufficient hold in the sheave to prevent slipping. To obviate this, a second sheave was placed on the same shaft, by means of which the rope had two holds in the groove instead of one, which was found to be quite sufficient, and the whole worked satisfactorily. Subsequently the hempen rope gave place to one made of wire.

After reaching the summit, the line passed about 1½ miles to the brow of the mountain on the opposite side, and then had a descent of near 500 feet in about one mile. To provide means to resist the preponderating gravity of loaded trains as compared with empty trains, was a serious matter. The method described, in European engineering, was by a friction brake ; to this, there were considered several objections, when applied to so large a preponderating force. It occurred to the writer that it might be possible to make use of the resistance of the atmosphere to secure the object. It was found that experiments had been made on this resistance, which so far as records could be found, were on a surface of one square foot, and it was deemed advisable to have them made on a larger area. Accordingly, I had an apparatus prepared, in which I could use a surface from 4 to 21 feet area. With this, I made a great number of experiments at different velocities, from which it appeared that the resistance was rather greater than in those referred to; whence I decided that air was the best element for controlling the preponderating force, and immediately set to work to devise the method of application.

The plan adopted was to place a large spur wheel on the upright shaft, immediately under the sheave wheel ; the spur, extending to each side of the road, worked the pinions of these shafts, and as the sheave wheel revolved, motion was given to the sails, which from their natural position, drove the air in opposite directions, and so prevented gyration. Each shaft had four sails made of thin boards, of about 20 square feet area. It will be noticed this was a very simple sort of machine. On one of the sail shafts was a powerful friction brake, to be used in stopping the trains at the head and foot of the planes, and for any emergency that might require it. This I called a pneumatic convoy. It will be readily apprehended that I felt no little anxiety in the success of the experiment as the first train was passed over the angle of the plane. Of course, the friction brake was at command, though its use was not required. The train moved off, the sails moved regularly and held it throughout to an

uniform velocity of about 4 miles per hour, as had been calculated; the result was complete. As business increased on the road, it became necessary to increase the speed of trains, and to reduce the area of the sails, and I believe, finally only their arms were left.

This plane was about ¾ mile long, and had a descent of about 350 feet. There were two other planes of this kind (called "self-acting" planes), to provide in part for the descent to the canal. The second was a short distance from the first, and thence the railway was carried on a grade of 1 to 120, about 6 miles, to the head of the third plane. On this grade, the loaded trains descended by gravitation. From the third self-acting plane to the head of the canal (about 3 miles), the road was constructed on a grade of 1 to 200. On this and also on the 6 mile grade, it was intended to use locomotive power—on the latter to haul back the empty cars. But this feature was abandoned, though the engines had been obtained. It was supposed the road would carry an engine of from 4 to 5 tons; they were made about one-half heavier. After repeated trials, it was decided the road was not sufficiently strong to sustain them with safety, and horses and mules were substituted in their place.

Now, this railroad has been materially changed. I left Mr. James Archbald, one of my Resident Engineers, in charge as Superintendent of the railway and the mines—that is, I recommended him, and the company gave him the superintendency. He had an excellent engineering mind, of great practical sagacity, and was eminently upright in purpose. After a few years he designed and executed an important improvement. In this, he abandoned plane No. 8 (the last self-acting plane), and carried the 6 mile-grade to the head of the canal at Honesdale. He then made a new plane worked by steam power, at the head of the canal, up which he hauled the empty cars to a certain height; and also a new railway on a grade that would allow them to descend by gravitation, as far as the country would permit; then by another plane of same kind, the cars were hauled up to such height as could be commanded, and a gravity railway was made as far as the ground would permit. So alternatively, by planes worked by steam and by gravitation, he completed a return railway from the canal to plane No. 7 (the second self-acting plane), a distance of about 10 miles. This dispensed with all moving power, and completed the machinery character of the railway. It is now worked by stationary steam and gravitation, with no moving power of importance.

Subsequently, Mr. Archbald was employed as the Chief Engineer of the Pennsylvania Coal Company, for which he constructed a railway from its mines at Pittston, through Cabb's gap and the valley of the Wallenpaupac to Hawley, a town on the Delaware & Hudson canal, about 8 miles from the head at Honesdale. This railway is about 40 miles long and wholly a stationary steam and gravitation railway, in both directions ; it has worked in the most satisfactory manner. It is obvious the above plan would only be useful when there was great disparity between the elevations of the valleys and adjacent hills. This was peculiarly the condition in these cases, and transportation was made at moderate expense over the mountainous country.

To return to the canal. Mr. Wright resigned the position of Chief Engineer about two years after the commencement of the work, and the writer was appointed to that position. In the autumn of 1829, there was some navigation on the canal, and a few hundred tons of coal were transported to tidewater. There were many impediments to the progress of navigation, but during 1830, there was considerable traffic, the work steadily improved and the quantity of coal delivered at tidewater was increased. I recommended Mr. Russell T. Lord, who had been a Resident Engineer on the canal, as General Superintendent. He was a man of excellent executive ability, and conducted the administration with great good sense and fidelity to his duty. The canal business increased, and after a few years, Mr. Lord made an improvement by increasing the depth of water, so that he raised the tonnage of the boats from 30 to 50 tons, increasing the capacity of the canal and the economy of transportation. In this, he only altered the locks, so as to meet the rise in water, leaving the chamber the same in width and length. The advantage that had by this means been realized, led to a more radical enlargement, by which the locks were rebuilt with chambers 90 feet by 15. instead of 76 by 9. The depth of water was raised to 6 feet, and the canal more or less widened. This would all have been well, had the widening corresponded, but it was not sufficient to give the proper ratio between the section of the boat and the section of the canal. The result was, it did not improve the economy of transportation; it however, increased the tonnage capacity of the canal, which was an ample compensation for the cost of the improvement. Mr. Lord replaced two, and added other two aqueducts by which the canal was carried over streams, supported by wire cables. The traffic of the canal, (mostly coal) increased much beyond

the original anticipation ; it is now carrying annually about 1 250 000 tons of coal, and is in a highly prosperous condition.

The original works cost about $2 500 000. This sum put in operation, 106 miles of canal of generally difficult construction, with 110 locks, and 16 miles of railway with an elevation of about 1 900 feet. The company obtained the credit of the State for a loan of $800 000, which was all punctually refunded.*

I must not forget to notice the aid I received in arranging the details of machinery, from Mr. John H. McAlpine (the father of Mr. William J. McAlpine †). Mr. McAlpine was an accomplished machinist, to whose superintendence I intrusted the machinery department, in which he performed his duties in a very satisfactory manner. While in this service, Mr. McAlpine introduced to me his son William, and requested that I should put him in one of the engineering parties. The son was then about sixteen years old, a light, but active and pleasant boy. Advancing from station to station, he was many years in my employ ; manifesting capacity, industry and fidelity, he was one of my most esteemed assistants. His subsequent career and standing is before the world, as among the eminent engineers of the country. He is still in the vigor of manhood, and can tell his own story.

The Mohawk & Hudson Railway.—In May, 1830, I left the service of the Delaware & Hudson Canal Company, except that I was to make occasional visits to the work for the then ensuing year, and accepted the appointment of Chief Engineer of the Mohawk & Hudson Railway. This line extended from Albany on the Hudson to Schenectady on the Mohawk. Its main object was the transportation of passengers. At that time, passenger boats on the Erie canal brought passengers from Buffalo to Schenectady, and together with the stage coaches, transported a large number.

The intermediate country was a table land of a fair character for a good line and easy grades ; but that was reached by a sudden rise of near 200 feet from the Hudson, and over 100 feet from the Mohawk. These rises were at that time regarded as requiring inclined planes, worked by stationary engines. Consequently, this railway was constructed with an inclined plane at each end. The adhesive power, the means of transmitting power by locomotive engines, was then regarded much

* I send to the Society, a number of the plans of structures on the Delaware & Hudson Canal and the Carbondale Railroad, which I have preserved.

† Member and Past President of the Society.

below what it was subsequently found to be. After working with the inclined planes a few years, their inconvenience for a miscellaneous traffic was demonstrated, and a commission appointed to ascertain the practicability of dispensing with them. I was a member of the commission, and examined the engineering view of the question. We found a line rising from Albany at a grade of 80 feet per mile, and from Schenectady of 40 feet per mile, which the commissioners recommended; the line was accordingly changed in this respect, and has subsequently been worked by locomotive steam power.

This railway was constructed with a double track. It had the ordinary features of railways at that time constructed in this country—namely a wooden rail capped with a plate of iron, which in the excavations was laid on stone blocks, and on embankments, with timber cross-ties. While in use, the inclined planes worked very smoothly, and I believe, no serious accident occurred.

A locomotive engine was made for this line by the West Point Foundry Association. It weighed between 4 and 5 tons, had 4 wrought iron wheels, and carried from 75 to 125 passengers in a train, at a speed of 25 miles per hour. A second locomotive was obtained from the works of Robert Stevenson, England, which weighed about 7 tons, and was much more powerful than the other. The first was named De Witt Clinton, and the second, John Bull. The action of the John Bull was observed to be rather severe on this kind of rail. It being placed on 4 wheels, the overhanging caused a sharp and disagreeable motion of the engine. This circumstance, with others that came under my observation, induced me to seek some remedy for the weight, and to secure a more steady motion. The idea of more wheels was natural for the first object, but to spread the base was supposed unfavorable for curves; and I was finally led to the plan of a 4 wheeled truck under the forward part of the engine, as a support for that end, and as a guide. By this I had 4, instead of 2, wheels and could place the trucks so far from the drivers as to cause less vibrating motion. A new engine was built by the West Point Foundry Association on this plan, and the truck was found to work satisfactorily. I then made a new plan for an engine for the Schenectady & Saratoga Railway (of which I was the Chief Engineer), and sent it to Mr. Stevenson, who built the engine. This engine weighed about 6 tons; it moved with perfect beauty, and I may be pardoned, I think, in saying that my first ride on it was a great delight. The smooth action of its parts, and the steadiness of its motion gave me great satisfaction. A

year or two later, the railway was extended westward, and from time to time, continued, until it reached the Pacific Ocean at San Francisco. On the entire route, the truck arrangement was considered as a complete success, and is now the general plan of American locomotives. The truck itself was not a new idea with me ; it had in principle been used, but was very generally supposed to be impracticable for high speed.

The Mohawk & Hudson and the Schenectady & Saratoga Railways were completed, and in April, 1833, I engaged with the Canal Commissioners of New York, as Chief Engineer for the Chenango canal.

The Chenango Canal is about 98 miles long and has about 100 locks. The cost was about $2 000 000; it extended from Utica on the Mohawk river, through the Oriskany and Chenango valleys to Binghampton on the Susquehanna. The route was moderately favorable. The most distinctive feature, is the resort to artificial reservoirs to supply its summit with water. At the day this canal was commenced, it is believed no such dependence was relied on, to supply canals in this country. Such means had been adopted to supply canals in Europe, and it had been held that one-third of the rain-fall could be depended on, over the loss by absorption and evaporation. As this ratio would vary in different situations, I decided to establish a rain gauge and a sluice for measuring the water that flowed from the valley. On one of the valleys, this was attended to daily for one year, and on another valley, from June to December. Mr. William J. McAlpine was the Resident Engineer on the Summit Section and had charge of the rain and sluice gauges. The matter was diligently attended to, and the result from these gauges was to establish 40 per cent. as the proportion of rainfall which on an average soil could be secured in a reservoir.*

During the time of my engagement as the Chief Engineer of the Chenango canal, the traffic on the Erie canal had been so large, that measures were in contemplation to double the locks and to enlarge the canal.

Erie Canal Enlargement.—The Canal Board had decided to enlarge the section to 5 feet depth and 50 feet width. This decision was not fully approved as being adequate to the wants of the future traffic, and the matter was discussed by the public, which caused indecision and suspended operations. My connection with Commissioner Bouck on the Chenango canal, led to much conversation on this matter, and at his re-

* The plan for one of these reservoirs as also for other structures on this canal will be found in the folio, labelled Chenango Canal and Erie Canal Enlargement, in the Society's Rooms.

quest, I investigated the question of the ratio the sections of boats should bear to the section of canal, deducing the comparative economy of transportation. Without dwelling on preliminary facts, I may state these discussions led the Canal Board to order a careful survey of the work, and estimates to be prepared on the basis of enlargement to a depth of 6 and also 7 feet of water, the widths being respectively 60 and 70 feet.

In accordance with the above, engineers were appointed to make the examinations on the respective sections as directed by the Commissioners, and to the writer the Eastern Section was assigned. The surveys and estimates were made in 1835. The surveys of this section were made by Mr. William J. McAlpine, who at that time was one of the Resident Engineers on the Chenango canal. Though I was in charge as Chief Engineer of this canal, I gave a large share of personal attention to the question of enlargement. It had appeared to me that errors had been made in the original work which it was important to correct, as far as practicable, in the enlargement. At a point about 8 miles above Albany, commenced the location of what was termed the "nine locks." In a distance of about 2 miles there were, I think, 17 locks. At one cluster the 9, and at another the 4 locks, had much contracted pond reaches, which was found to be very unfavorable to the large traffic that then existed. I directed Mr. McAlpine to commence a survey at a point about 1 mile below the 9 locks, to run the level above the 4 locks, and ascertain if it was practicable to find ground on which these locks could be located so as to give a pretty uniform space for the pond reaches between them. The ground was pretty rough and rocky, but a satisfactory location was found, that allowed the locks to be very evenly distributed on a new line about 3½ miles in length. I therefore recommended the Commissioners to abandon the old for the new line; this was done and the new line constructed, which has proved a very satisfactory improvement.

A short distance beyond the point above referred to, the canal line crossed the Mohawk river to the north side, was continued on that side 12 miles, and then crossed back to the south side of the river. This involved two aqueducts over the river, averaging each, near 1000 feet in length. I had a line continued on the south side of the river, with a view to judge of the propriety of dispensing with the aqueducts. The surveys and estimates induced me to recommend the abandonment of the canal on the north side, and of course the two aqueducts, and to adopt the new line on the south side of the river. On this question the

Canal Board was equally divided, and of course, the recommendation was not adopted.

The next point of importance in changing the original plan, was on a section from Schoharrie creek, to a point, 4 miles above. On the west bank of Schoharrie creek, the canal was locked into it, and by means of a dam, a pool was made as the channel of the canal across the creek. At the point 4 miles above, was another lock, and about midway on this section, a pretty large creek, though much smaller than the Schoharrie, crossed the canal by means of a dam. These were turbulent streams, and often the source of much vexatious trouble to the navigation. I proposed to take up the 2 lift locks, by which the level of the canal was raised sufficient to cross over both the streams by aqueducts. This change the Canal Board sanctioned, and it has been a great benefit to the navigation.

There were other streams crossed by means of dams for which I arranged the levels, so as to be crossed by aqueducts. This method provided for putting small streams under the canal by means of culverts, many of which from the low level had been allowed to flow into the canal. At the Little Falls of the Mohawk, I wholly rearranged the flight of locks.

The surveys on the canal west of my section were made by Messrs. Nathan Roberts, F. C. Mills, and Holmes Hutchinson. The instructions of the Canal Board did not propose nor ask the several engineers to express opinions as to what size they regarded most appropriate, but Mr. Roberts and Mr. Hutchinson had given their opinion in submitting their report. On discovering this, Mr. Mills and myself made a special report on this point. We declared in favor of 8 feet depth and 80 feet width, which was the size I had regarded most suitable. The Canal Board, however, decided on 70 feet width and 7 feet deep, and it has been so constructed. The plan of stone arches for the towing-path on the aqueducts, when the height required a timber trunk for the boat channel, was proposed by me at the same time, and has been adopted in the subsequent works on the canal.

Early in the year 1836, the Canal Board decided to proceed with the improvement as above stated, and on the Eastern Division to make double locks. Plans and specifications of the work were proposed, and contracts made early in the summer of 1836, and the work commenced. With Mr. William J. McAlpine as Principal Assistant, I was appointed Chief Engineer of the Eastern Division.

No one appreciated more than I, the importance of substantive and durable works, but unfortunately at that time, there was so high an estimate of the value of the canal, that the ideas of men were extravagant, and advocated work of an expensive character, that was in no way more substantial or useful. This induced a more or less expensive policy, that increased the cost of the work much beyond what was necessary. I had recommended, that the chambers of locks for a canal 7 feet deep by 70 feet top width, should be 16 feet wide and 115 feet between the gates. The Canal Board, on the petition of navigators, increased the width to 18 feet, which I regarded a decided error. A navigation with few boats may be conducted on a comparatively narrow channel; but for a large traffic, there is a proper relation between the area of boat and area of channel that secures the best economy in transportation. The boatman will make the boat as wide as he can pass the locks, with simply room to pass on the open canal. They analyze nothing, but suppose the acme of economy is in the largest possible load they can carry; very much on the theory of most railway superintendents who consider the largest possible train as securing the best economy in transportation, with no more attempt at scientific analysis than that of the boatman. It is now the opinion of the most intelligent navigators of the canal, that the locks are too wide for the best economy of transportation.

The Croton Aqueduct.—In September, 1836, a committee of the Croton Aqueduct called on me with a proposition that I should accept the position of Chief Engineer of that work, and in October following, I accepted the position. The Canal Commissioner (Hon. William C. Bouck), with whom I was especially associated, was reluctant to have me leave the canal, but said he would not object to my accepting the charge of the Aqueduct if I thought it my interest to do so. I have been charged with intriguing for the engineership of this work, but that is an entire mistake, as I had not mentioned the subject to any one, and consequently was quite surprised at receiving the proposition. All the intercourse I had had on the subject, was an answer to a letter of the Chairman of the Croton, Aqueduct Board, requesting me to send him any copies I had of the forms of contract and specifications of the State canals, in which there was not the least allusion to my having anything to do with the work. At first I declined the offer, not feeling willing to interfere with Major Douglass, who, I knew, had a high estimate of the professional importance of the work. But the committee placed the matter on the distinct ground that they had decided a change was necessary, that I was preferred, and

if I did not accept they should seek some one else, and they wished me to consider Major Douglass as out of the question. Under such circumstances, I saw no impropriety in accepting a position that appeared professionally desirable, and offered without the least effort or knowledge on my part. Accordingly I resigned my position on the Erie Canal Enlargement, and Mr. McAlpine, my Principal Assistant, was appointed to succeed me.

Surveys had been commenced in 1833, with a view to examine the feasibility of introducing the waters of the Croton river into the city of New York. Major D. B. Douglass was occupied during the seasons of 1833–34, and made estimates and reports of his surveys. Mr. John Martineau was engaged on the same in 1834. They made independent surveys and reports to the Board of Water Commissioners, and substantially agreed in recommending the Croton as the best source for supplying New York with water. In neither case, was there much presented as to definite plans of the works, by which the object was to be secured; these were left in general form, for future elaboration.

In the spring of 1835, the city of New York accepted the plan and authorized the Board of Water Commissioners to proceed with the construction of the work. Messrs. Stephen Allen, Saul Alley, Charles Dusenberry, Benjamin M. Brown, and William W. Fox constituted the Board. They appointed Major Douglass, Chief Engineer, and instructed him to proceed to locate the line and prepare plans and specifications for the work. He made the location of the line of aqueduct from the Croton river to the North bank of the Harlem river, 33 miles; and determined the grade of the aqueduct at about 13¼ inches to the mile. It was in the main, well located.

In regard to plans of work, he proposed a cross section of the masonry of the conduit, which with some modification was adopted. So far as I have known, he prepared no specifications for the work that were approved by the Commissioners. I am thus particular, for the reason that Major Douglass' friends have claimed for him the credit of preparing the plans on which the work was constructed. In addition to the above, some plans of bridges and culverts were prepared by him, but none of them were adopted. He had been occupied on the work as Chief Engineer about one and a half years after it was authorized. In whatever follows,* the plans and specifications of the several works were prepared

* I shall not go into particulars in relation to the plans, except it may be, in regard to some peculiarities, as I have prepared a folio of the drawings and of specifications of the manner of work, which is at the rooms of the Society, and to which I refer.

by the writer exclusively. I proceed to give some particulars of the more important plans of the work.

The Dam across the Croton River was proposed for the head of the aqueduct, and required to be above the surface of the river, 40 feet, to meet the grade of the aqueduct at its head. The south side of the river was a rock, rising from the water at about 1 to 1½ to the head of the aqueduct. The dam and its abutments on the river side were built on rock, and the extension of the weir was made by excavating the rock into the hill. But I need not take space for this part of the work. The length of the weir was too short for the flood that came just before the dam was completed, and the embankment that connected the dam with the north shore of the river gave away. The masonry of the dam was not at all disturbed by the flood, though the water rose 12 feet above the level of the overfall or lip of the dam. The distance from the abutment to the hill on the north side of the river, was about 200 feet. I had hoped, by confining the dam to the rock on the South side, to secure the benefit of the rock to break the fall of water in times of flood, which would have been very well had the length of weir been sufficient. The result showed this to be an error: I then recommended that the dam be carried entirely across from the old abutment on the south side to the high grounds on the north side, making an extension to the weir of the dam, of 180 feet.

There was no rock for a foundation at this part, and all the works required to be artificial. The great point in such cases, is the means of counteracting the fall of a large body of water, over artificial works 40 feet high. The plans show this to be done, by giving a curved form to the lower side of the dam, by which the course of falling water is gradually changed from a vertical to a horizontal direction, when it reaches the apron and the reaction of the water in the river below. The curve in this case has worked very satisfactorily, the water in a high or low stage, following close on the face of the masonry. There was no reasonable way of turning the course of the river during the erection of the work, and no means to provide for the water except the waste culvert in the old dam, which was about 6 feet above the surface of the river. The ordinary width of the river was about 100 feet, and the greatest depth of water, 15 feet. The culvert above mentioned and temporary sluices over, were the only means for protecting the work, in floods that occasionally occurred in the river. It will readily be realized that for the long time required,

this was a work involving great anxiety, in any prospect of rain. The first season, the work was carried up about half its height, and then covered by a plank and timber aproning, to protect it from the winter and spring floods. Through the kind providence of God, the storm was so tempered that the work proceeded until completed, with little interruption, except that of the winter.

Though varied methods were adopted in preparing the foundation, and bringing the work up to the surface level of the river, there has occurred no settlement to mar the work or materially to affect its level. So far as I know, the dam is in no essential respect impaired after 33 years' use, though at one time a flood rose to the height of 8 feet on the crown or lip of the dam.

General Work of the Croton Aqueduct.—The method of constructing the conduit, the form of ground at different places, the ventilators, the waste weirs, culverts and the foundation walls, are explained by the plans, the form of contracts, and the specifications sent herewith.

Sing Sing Bridge.—The only peculiarity it is necessary to notice, is the plan of cast-iron lining for the conduit. This was introduced in order to guard against leakage that by possibility might percolate through the masonry. There was good reason to suppose such would be very small, and of no importance as to waste of water; but in this climate, leakage amounting to only a sweating of the arch stone in the bridge masonry, would tend to disintegrate the most durable stone, and it was therefore important to arrest it by every means practicable. This iron lining appears in the cross-section of the conduit over the bridge. The method has been in the main successful, though it requires some attention to correct the effect of longitudinal contraction and expansion. I would recommend for such cases, an iron pipe, put together with faucet and spigot joint, as a more perfect method. Of course, it would require a large pipe to carry the water of the conduit without extra fall, but it is practicable to cast pipe of sufficient size for the Croton conduit.

The centering of the Sing Sing arch was on the plan adopted for the Waterloo bridge at London, and is an excellent one for such arches. As an evidence of the close joints of the masonry of this arch, I had a level taken before striking the centres, and found the settlement of the arch was less than half an inch. The work in this arch has no superior, in comparison with other arches of this size, and of which this item is recorded. The span is 88 feet.

The Harlem River Bridge is about one quarter of a mile in length, and about one-half or 600 feet, is across the Harlem river. The plan shows the bridge to be about 114 feet above tide water. The bed of the river was a deep mud, interspersed with large boulder stone, mostly from 500 pounds to 2 tons, and some of much greater weight. The subsoil under the mud was in some places, rock in place, and at other parts a clean sand. We found no boulders of any amount after striking the sand. The depth of water in the channel was about 20 feet. In the deep part of the channel there was only very little mud. The boulders mentioned above, were very troublesome to the work of driving the sheeting timbers of the coffer dam. After the coffers were emptied, many of the sheeting piles were found broken into shivers, which caused much trouble in managing the coffers. In the line of the coffer sheeting, many of the boulders were "lewised" and hauled out from 10 to 15 feet below the surface of the river. Boulders weighing 15 tons were so removed, but those left, gave the difficulty referred to.

The great point in supporting a bridge of this height, was to so prepare the foundations, that there would be no unequal settlement in the masonry. As some of the piers were on solid rock, and others on pile foundations, it was a subject of much anxiety. For the central pier that came in the channel, the excavation within the coffer dam was carried down, nearly 40 feet, without finding any material but sand. A boring in this coffer for a depth of 50 feet showed only sand. Piles, 12 inches in diameter, were then driven, mostly 35, and some 40 feet in length. It will be noticed, these piles were driven to a depth of 80 feet in some cases below the surface of the river, or 194 feet below the parapet of the bridge. A course of white oak timber was fitted on the heads of each row of piles, and the space between, filled with concrete masonry. Then a second course of white oak timber was put across, on the first course over the piles, and the spaces filled as before. On this, the masonry of the pier was commenced. The foundation was made much larger than the shaft of the pier, with offsets to about the surface of the river. In all the pile foundations, it was meant to give such breadth as would be a protection against settlement.

The bond in the courses of masonry in the piers, was thoroughly secured by preparing a plan for each course, and requiring every stone to conform to the plan. It will be noticed, the shafts of the piers are hollow, which was not new, as it had been practised in European bridges.

This bridge has now stood about thirty years, and I have not known of any failure.

The plans I present, will show the arrangement for pipes. It was made for two 4-feet pipes, this being equivalent to the capacity of the masonry conduit. As a measure of economy, and a plan that would provide for the wants of the city for many years, the Water Commissioners decided that 3-feet pipe should be put down, to be replaced with 4-feet pipe when necessary. I preferred two pipes, as affording the facility for repairing or removing one, while the other would supply the city. The gate houses were arranged for 4-feet pipe, and all that was necessary was to take up one line of 3-feet pipe and put down one of 4-feet, as more water was wanted. As subsequent events have shown, it would have been the best economy to have put the 4-feet pipe down, in the original construction; for in some way, the management did not take up either of the 3-feet pipes when more water was wanted, but placed a wrought iron pipe over them, raising the parapets of the bridge, and incurring a much larger expense than would have been required by the 4-feet pipes in the outset. I protested against this, as marring the simplicity, economy, and usefulness of the original plan, but I had not then any official charge, and my protest was unheeded.

The plans referred to,* show the details and method of the pipe works across Manhattan valley, and description does not appear necessary. The same may be said of Clendining bridge, and of the receiving reservoir.

The Distributing Reservoir.—The leading feature of this, is the plan of hollow walls. The retaining walls were required to sustain a pressure of 40 feet of water. The natural surface of the ground was about the level of the bottom water line of the reservoir. A solid retaining wall of this height would require to be very thick. A single thick wall has the objection that it requires more time to ripen, or become well set in the cement, and further, the cost of such a wall will be greater for the same support than a wall having a broader base and less aggregate material. In this view, I prepared the plan of a hollow wall, that is, two parallel walls connected by cross walls, and the cross walls connected at the top by brick arches. This kind of work was carried up within about 12 feet of the top or coping of the reservoir, and then a single wall completed the work. An

* For a list of the plans referred to, here and elsewhere in this paper, see March Proceedings, (Vol. III,) "Additions to Library and Museum."

opening was left in the cross walls so that a man may go round the whole and discover any leak there may be in the masonry. The working of this plan has proved very satisfactory.

I send herewith a description of the Croton Aqueduct, written in 1842. Some slight modifications occurred in the unfinished works after this was written, but nothing of essential importance.

Cochituate or Boston Aqueduct.—The city of Boston had made an unsuccessful effort to procure a supply of water. The difficulty arose from a divided opinion as to which of several projects was the best. A Board of Commissioners had reported the Cochituate as the best of the several projects, but the opposition of the friends of other projects was so strong, that the measure was defeated by a vote of the citizens, in the spring of 1845. Not willing to abandon an enterprise so important to the interests of the city, the City Council appointed a committee to institute necessary measures to secure a supply of water. This committee decided to select a commission, consisting of one person from the city of New York, and one from Philadelphia, to make an investigation of all the projects that had been presented, and report such as they should find to be the best.

For this, they engaged Mr. Walter Johnson, of Philadelphia, (a Professor in a scientific institution,) and the writer of this Memoir. I went to Boston, and there met Mr. Johnson, and the members of the Water Committee.

After making some general examination, it was apparent to me that the duty was essentially a matter of engineering, and that under the circumstances existing, it would demand very careful examination and great prudence to bring out successfully the varied features of the proposition. Not having any previous personal acquaintance with my associate, with the fact that he was not professionally an engineer, I concluded not to enter upon the service, unless the engineering was placed entirely in my hands. This decision was not favorably received by the Committee or Mr. Johnson, but I thought "one poor general was better in command than two good ones," so I adhered. The Committee urged that it wanted the moral force of two commissioners; "very well," I said, "the report may be made in the plural, and I shall have no objection to Mr. Johnson signing it with me, and he may be charged with certain duties that will not conflict with the general engineering." To this the committee assented, and the investigation proceeded.

I engaged Mr. Henry Tracy, a civil engineer of experience and ability, to take charge of the surveys and estimates, a service he performed with prudence and ability. In about five months, the examinations and report were completed, by the recommendation of the Cochituate as the best source.

As a suggestion, that may be useful to the younger members of the profession—I kept strictly my own opinion until it was tested by the result of a full examination ; not even my confidential assistant ever obtained from me, the least expression of my views. This was not because I was afraid to trust him, but that he might say at all times, he did not know my opinion. In such a case, there is great anxiety with the different parties to obtain knowledge of the prospect of their respective projects, and the least intimation would inevitably lead to discussion. At one time, the Committee was impatient to get my views. My associate had been rather leaky, but he was unable to quote me, and the Committee appeared to think I should at least give them an intimation. I replied, they would know my opinion when they had it in writing at the end of a report. They were not satisfied, and seemed to think I had not treated them with proper deference. In the final result, they expressed themselves as well satisfied with the course I had pursued. The report of the Commissioners was generally satisfactory, and the work was authorized to be constructed.

The work for the aqueduct was commenced in the spring of 1826. The Board of Water Commissioners was composed of three members, Messrs. Nathan Hale, James Baldwin, and T. B. Curtiss ; Mr. E. S. Chesbrough, was appointed Engineer of the conduit and its appurtenances, and Mr. William E. Whitwell, of the piping in the city. The writer was engaged as Consulting Engineer, and continued to the close of 1848, when the works were completed, and the water introduced in the city, with enthusiastic demonstrations by the citizens. Any further description I properly leave for the acting engineers, who had charge of the construction of the work.

The Hudson River Railway.—Some surveys and estimates had been made for this enterprise, mostly by the aid and influence of Mr. James Boorman, a wealthy and spirited merchant of New York. The project, however, did not obtain much favor with the public. It was generally regarded as unpromising, in view of the competition of the excellent navigation of the Hudson river. In the summer of 1845, Mr.

Boorman called on me, to enlist my services in the examination of the project. I had a favorable opinion of the enterprise, but well understood the difficulty in convincing capitalists that it would be a commercial success. The general character of the country for such a work clearly indicated that it would be expensive, and the competition it must meet from a steamboat navigation conducted on a magnificent scale, led the public to regard it as an extremely hazardous, if not a hopeless enterprise. After considering the proposition of Mr. Boorman, I decided to engage upon the work, and during the ensuing autumn employed Mr. Henry Tracy to make such surveys as the season and limited funds would permit.

Having given my attention to the project, I devoted much time to gathering and analyzing statistics, mostly as to passenger traffic. Mr. Tracy conducted the surveys with great skill, and for the limited means he had, obtained important information. His services were directed to the section between New York and Fishkill, about 60 miles. For the balance of the line, the survey of Mr. Morgan—which left the river at Fishkill, and pursued an inland route—and his report, was the basis of the report I made to a company of citizens in January, 1846.

Under this report, a charter for a company was obtained and the corporation organized. Generally the public mind was sceptical, and subscriptions to the capital stock progressed slowly. The indomitable energy of Mr. Boorman succeeded in raising the amount to $3 000 000. Loans were depended on, for the balance required.

From the general want of confidence in the undertaking, the organization was not perfected until late the following winter. In the spring of 1847, the Board of Directors appointed the writer, Chief Engineer of the railway, and proceedings were had to commence the work soon after.

As surveys for actual location proceeded, it was soon evident there were obstacles to be encountered that had been very imperfectly developed by the limited character of the original surveys. The rock cuttings in the Highland districts proved to be unusually difficult of excavation. Very little earth could be had in this district for the fillings, and to make these of rock cuttings, especially in those places where the fillings sunk to a great depth in the mud, was very expensive. The long line of exposure to the surf of the river was a serious matter. The great difficulties of the work lay between New York and Poughkeepsie. Above

the latter place, the rock was of a slaty character and easily excavated, and the shore had less exposure to the action of the river.

After a more careful examination of the inland route, and also by a survey of the river route made by Mr. John T. Clark, an Assistant Engineer, I made a report to the Board of Directors in January, 1848. In this, I recommended the adoption of the river route for the whole line. This report was approved, and the work has been constructed on the river route. It was open for transportation to Poughkeepsie about the close of 1849. For the most part, this section of the railway was graded for a double track, but only a single track was laid at this time. No work of construction had been done above Poughkeepsie.

In August, 1849, I resigned the position of Chief Engineer, and Mr. W. C. Young was appointed in my place. I continued, however, as Consulting Engineer until the spring of 1850. At this time, I found that my views in regard to the management and operation of the railway did not harmonize with those of Mr. Boorman, and I therefore resigned and have had no connection with it since then.

It is impossible at this day, for any one not engaged in the persistent efforts of the time, to appreciate the hardy character of this enterprise. The financial and engineering difficulties were very great. In regard to the former, I can hardly conceive that more could have been done than was effected by Mr. Boorman and a very respectable Board of Directors. In regard to the latter, the natural impediments were rendered especially severe by difficulties of finance. These in the face of competition from steamboats of great magnificence effecting very cheap transportation, and the incredulity of the public mind as to the capacity of the railway to maintain such competition, rendered the prosecution of the work extremely embarrassing.

The landed proprietors along the route were in general very hostile to the enterprise, declaring it would destroy the natural beauty of the country as well as fail in its commercial object. On this point I had claimed that the natural scenery would be improved; the shores washed by the river would be protected by the walls of the railway, and the trees, no longer undermined and thrown down by the river surf, would grow more beautiful; and that the railway thus combining works of art with those of nature would improve the scenery. For this I was freely reproached as scarcely less than a barbarian. As to my very modest statement, that the railway trains would be able to travel at the rate of

30 miles per hour. I was called to account in some very decided poetic effusions.

I wrote an article published in *Hunt's Merchants' Magazine*, in November, 1846—in which, discussing the subject generally, I took the ground that not only along the Hudson, but also on other steamboat routes, the railway would be a successful competitor. In this article, speaking of railways, I said "The system is viewed as one that mocks the age, its progress has startled the most cautious, its developments are revolutionizing the social and commercial affairs of mankind." This was criticised as a very presumptuous statement. I notice these matters as curiosities of the time. At this day it would be difficult to find any landholder, or steamboat man, to assert the same things. The railway has traveled on, and more than reached the position then claimed.

European Tour.—On the closing of my connection with the Hudson River Railway in the spring of 1850, I concluded to make a trip to Europe. My health had been impaired by severe and long-continued labor, and I had for some time indulged a desire to make such a tour, hence I embraced the opportunity. The trip was of great interest, and afforded me much pleasure.

It so happened that while I was there, one of the large tubes of the bridge over the Menai Straits was to be launched. Mr. R. Stephenson kindly gave me an invitation to witness the operation. The spectacle was highly interesting in itself, and was followed by an invitation to dine with a party of English engineers, an occasion I enjoyed very much. I noticed that they far excelled me in making speeches, which was quite the order at dinner. It was an art I had not cultivated, and I expressed to them my surprise at the skill they exhibited in this respect. It is not worth while to go into particulars of this tour. I will simply state that my observations were mostly on engineering work which interested me very much.

I returned after an absence of four months, greatly improved in health, and immediately engaged in the construction of the

Michigan Southern & Northern Indiana Railways.—They were practically one railway, about 246 miles long, extending from the head of Lake Erie to Chicago, on Lake Michigan; about 66 miles had been constructed by the State of Michigan, with a timber rail and iron plate. It was now in the hand of an incorporated company, which had a section of 18 miles nearly completed, and laid with iron rails. I spent most of the winter of

1850-51 on the line of this railway. There remained about 160 miles to be constructed. The route was very favorable. This portion of the work was entered upon in the spring of 1851, with vigor, and in about one year, a line was opened to Chicago. The principal difficulty was one of finance. Though the work was of very moderate cost, eastern capitalists were very reluctant to enter on an enterprise in the western States, as several had repudiated their debts, and this impaired confidence in the honesty of their institutions.

During the summer of 1851, I engaged as President, in the construction of the Chicago & Rock Island Railway, extending (as a continuation of the Northern Indiana Railway) from Chicago to the Mississippi river at Davenport, 180 miles. This was also an easy line to construct, and was brought into use in 1854.

I continued my connection with the Michigan Southern & Northern Indiana Railway until the spring of 1858, when it became obvious my views of management could not prevail. With the exception of incidental services, I had no professional engagement until December, 1861.

Pittsburgh, Fort Wayne & Chicago Railway. This road was 468 miles in length, extending from Pittsburgh, to Chicago. It had been constructed under financial embarrassments, and as usual in such cases, was poorly built. There were first and second mortgages on the railway, for about $10 000 000, and a floating debt of between $2 000 000 and $3 000 000; the capital stock was about $6 000 000 making a total liability of about $18 000 000. The company defaulted on their interest, and after two or three years, the bondholders foreclosed and sold the railway in the early part of the autumn of 1861. From inferior construction and inadequate maintenance, the line, at the time it was taken in charge by the Trustees of the bondholders, was in very poor condition.

In this state of affairs, I was appointed General Superintendent. The stock and floating debts were very honorably provided for by the Trustees. For the floating debt, a third mortgage was given to the holders of claims, conditioned that no interest should be paid until a sufficient surplus had been earned therefor, after providing interest and sinking fund for the first and second mortgage bonds. After the net income should thus provide as above, for all the bonded debt, then the stockholders should be entitled to any balance obtained from net income. I mention these particulars as very creditable to the Trustees, and in striking contrast with the action of bondholders in some other cases.

The capital stock was very low in the market. I was informed that it had been sold at 8 per cent. Not long after I had entered on the management, a stockholder enquired of me to know if I thought advisable to sell at 20 per cent. I replied that I could not advise in such cases—that I regarded the prospect of traffic as good, but the poor condition would require large expenditures to put the railway in even reasonable order.

The Trustees were extremely solicitous to secure such net earnings as would provide for the interest and sinking funds of the first and second mortgage bonds, saying, that beyond such provision they were willing all earnings should go to the improvement of the railway. In order to secure their object, the Trustees required a monthly sum to be placed in their hands.

I will not detain you with further details, but merely give the financial result. The first year passed with decided expression of satisfaction, and at the end of the second year, there were further net proceeds. After 2¼ years, I resigned the superintendency, but continued to act as Engineer until 1866. The bonds, in interest and sinking funds had all been provided for in these 2¼ years, and such surplus was in hand, that soon after, the Board of Directors declared a dividend on the stock at the rate of 10 per cent. per annum, which rate has not since been reduced.

Engineers as Railway Superintendents.—Now, it may be said, why all this about the superintendency of a railway—engineers are not much engaged except in construction? My object is to show that an engineering education fits a man best for the superintendence, no less than for the construction of a railway. I regard it an error that the profession has not given more attention to superintendence of operations. It demands the same thoughtful analyzing mind, to operate, that constructs. I have presented this case, to impress the importance of employing the best engineering experience and ability in the superintendence of railways. The case is a plain one. Say, management has failed to pay interest, and the railway was sold by foreclosure of mortgages. An engineer takes charge, and in 2¼ years this is all changed and the property becomes a success. But why an engineer? A true engineer first of all, considers his duties as a trust, and directs his whole energies to discharge the trust, with all the solemnity of a judge on the bench. He is so immersed in his profession that he has no occasion to seek other sources of amusements, and is therefore always at his post. He has no ambition to be rich, and therefore eschews all commissions that blind the eyes and

impair fidelity to his trust. His ambition is to make his trust a success to the proprietors. His education fits him to analyze facts, and more successfully than a layman to produce the best results of administration. To reach the best results of railways, they must be put under the superintendence of competent engineers.

It may be inquired, why should not engineers seek to be rich? certainly, they need the benefit of pecuniary resources as well as others, which is not denied. *Rich* is a relative term. The man who, by a proper economy, is able annually to lay something by as an investment from his earnings, is only exercising the prudence necessary to provide for age or infirmity. This all men should do, and it is especially important for an engineer, that by this means his mind may be at ease in regard to the future. What is meant by a thirst to be rich, is a speculating turn of mind, which is sure to prevent any especial eminence in an engineer. He should be careful to secure a proper salary, and then give his undivided attention to the duty he assumes. I have known several engineers who were always on the alert for speculation, but I have not known one such to secure any valuable standing as an engineer. To this it may be said, engineers have not, in all cases, succeeded in conducting the operating business of railways. The same may be said of lawyers, or any other profession, and it is just as important that the party in interest select a competent and faithful engineer as a competent lawyer. The same discretion is necessary in one case as in the other.

Being now past four score years of age, I can have no other motive than the public good in the above remarks. I make them in view of much personal experience, which has brought me to the conclusion, that the railway and kindred public works will not realize their legitimate benefits until their supervision is committed to competent engineers. In order for this, it is necessary to cultivate the profession so as to secure the qualifications and character before named, to carefully avoid all theories that are not based on well established and thoroughly analyzed facts, and to be very cautious before applying any theory, to see that all the facts involved are obtained, and that none are hastily and inconsiderately assumed. The profession is one of great importance to the public interest, and no pains should be spared to fully qualify those who pursue it for every engineering emergency, and to fit them for the discharge of every duty with scrupulous fidelity.

DISCUSSION ON THE

CROTON WATER WORKS AND SUPPLY FOR THE FUTURE.*

Mr. J. James R. Croes.—Referring to discussion on conduits, Mr. Theodore B. Samo, Assistant Engineer, Washington Aqueduct, writes:

"I see that Mr. Hutton† referred to me as authority for the statement that on the Washington Aqueduct where the conduit leaked over an embankment, the leak was stopped by raising and widening the embankment. His statement is correct. It may interest you to know that at the time of the leak the embankment was 14 feet wide, and that I had it widened to 30 feet, and raised, so that there is not less than 5 feet of earth on top of the arch, including the Macadam road—12 feet by 1 foot deep."

"The width of 30 feet was not adopted simply to stop the leak, but for the convenience of travel, as the conduit road has become in summer a great thoroughfare. I will not assert positively that the conduit does not leak, but at all events no water shows through the embankment. The embankment referred to is the first one above the distributing reservoir."

Two high embankments near Cabin John bridge used to leak, and were treated in a similar manner, with like results, the roadway being made 25 feet wide. The flow line of the distributing reservoir is kept at such a level that from Cabin John to the reservoir, the conduit is under a head. The head at the outlet is generally 4 feet, and has been as high as 5.8 feet.

Errata.—Volume V. On page 395, thirteenth line, for "where" read "when"; on page 396, seventeenth line, for "that" read "the"; on page 397, twentieth line, for "15" read "1.5"; on page 403, thirtieth line, for "the" read "on the"; on page 406, eighth line, for "during" read "through"; on page 413, sixteenth line, for "the channels" read "channels," and eighteenth line, for "of" read "off"; on page 417, twenty-sixth line, for "Segonia" read "Sequonia;" and on page 425, twenty-first line, for "convince" read "convince us."

Also on Plate II, the Jetty at *L*, should be marked "Jetty No. 1," and the one opposite, running out from the reef, "Jetty No. 2."

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* Continued from Vol. V, page 275. † Vol. V, page 260.

PROCEEDINGS

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–March 15th, 1876.—Fall of an iron bridge, a scale for discharge of water in jets and from mains, and a new system of telegraphy described, 37;—the quantity of masonry in East River Bridge, and notebook of SIMEON S. POST referred to, 38.

–April 5th, 1876.—Ballots for members canvassed, profile of South Pass bar, Mississippi river, presented, failure of dam at Worcester described, "Notes and Suggestions on the Croton Water Works and Supply for the Future" discussed, 47; a "Water Conduit under Pressure" announced, remarks made upon peculiarities of metals under strain, recent experiments on railway traction illustrated, resolutions relating to appointment of special Committees to report upon Failure of Dam at Worcester, and upon Resistances of Railway Trains, referred, 48.

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American Society of Civil Engineers.

PROCEEDINGS.

Vol. III. February, 1877.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

JANUARY 17TH, 1877.—A stated meeting was held at 8 o'clock P. M.

Communications* from Messrs. Charles W. Copeland and Francis Collingwood, giving account of the "Mount Washington Railway, (N. H.), its construction and operation," were read and discussed. A photograph of a portion of the railway, showing the center rail and the style of locomotive engine used, was exhibited.

It was announced that the American Institute of Mining Engineers would hold a general (quarterly) meeting in this city, beginning Tuesday, February 27th, next,† and the Institute was invited to meet at the rooms of the Society.

"Facts and Opinions in regard to Failure of the Railway Bridge at Ashtabula, Ohio," were then considered. Extracts relating to the matter, from newspapers and other sources, with illustrations of the structure and its site were presented.

Mr. Charles Macdonald, who had examined the wreck, soon after its failure, described the plan of the bridge, and its appearance after the disaster; a general discussion followed.

FEBRUARY 7TH, 1877.—A regular meeting was held at 8 o'clock P. M.

The vote on admission to membership was canvassed and the following declared elected:—Members—Frederick S. Benson of Brooklyn, N. Y.; Eckley B. Coxe of Drifton, Pa.; William C. Gunnell of Hartford, Conn., and David E. McComb of Washington, D. C.; and Junior, Sandford Horton of New York.

At the same time, the vote ordered December 6th, 1876 ‡ (under resolution presented at the Eighth Annual Convention §), upon appointment of a Committee to report to the Society, a form of Memorial to Congress in furtherance of the adoption of a metric standard, was canvassed, with the following result—ayes 138, nays 73, and blank 20.

* See page 12. † See page 18. ‡ Vol. II, page 173. § Vol. II, page 85.

A paper by Henry F. Walling, C. E., of Boston, Mass., on "Co-ordinate Surveying" was read; also—as relating to the same subject—extracts from a recent report upon the "New York State Survey."

Attention was called to the next meeting of the American Institute of Mining Engineers; the first session to be held at the Society's Rooms Tuesday evening, February 27th; a session also to be held Wednesday evening following, when an informal discussion will be had on the "advisability and practicability of adopting, in this country, the metric system of weights and measures"; members were invited to attend.

"Facts and Opinions, in regard to Failure of the Railway Bridge at Ashtabula, Ohio," were taken up. Communications from Messrs. G. K. Warren, E. N. Beebout and E. S. Philbrick, were read, and the subject was further discussed by Messrs. William P. Shinn, George S. Morison, and others present.

OF THE BOARD OF DIRECTION.

February 7th, 1877.—A stated meeting was held at 3 o'clock P. M.

The manner of keeping the accounts of the Society and appropriating its funds, was considered and a plan adopted; the stated meetings were placed under the direction of the President, Secretary and Committee on Library, to arrange papers, reports and other subjects for consideration, the order of business and to give special invitations to attend; recommendations from the Committee on Library, regarding copyright, and title of the Society's monthly publications and the publication of reports, were presented and acted on; the Treasurer's report of receipts and expenditures for quarter ending January 31st, was accepted, appropriations were made, and other business transacted.

February 9th, 1877.—An adjourned meeting was held at 10 o'clock A. M. Proposals for admission to membership were considered.

REPORT OF COMMITTEE

On Finance, for Year ending Oct. 31st, 1876.

Accepted January 3d, 1877.

We have carefully examined the Treasurer's accounts of receipts and expenditures, and compared them with entries and vouchers, and find them correct. We have also examined the securities of the Society in the hands of the Treasurer, deposited for safety in the vault of the Central Safe Deposit Company, (corner of Twenty-third street and Sixth avenue). These securities are as follows:

1	Bank-book, Seaman's Savings Bank for Savings (balance*)	$764 17
1	$1 000 bond, Norman Medal Fund	1 000 00
8	$1 000 bonds, Fellowship Fund...	8 000 00
1	$500 bond, " "	500 00
	Making a total † of.....	$10 264 17

* July 1st, 1876. † See detail report of sub-committee.

Some modification of the system of disbursing the Society's funds seems desirable. It has been suggested that at intervals through the year, the Finance Committee, after ascertaining the balance at the time on hand, should designate the amounts applicable to the ordinary expenses and the sum that could be devoted to increase of the Library, etc.; but, on account of the irregularity in the periods and amounts of the payments from members, etc., this is not as feasible as it might at first view appear to be. Thus, during November and December, 1875, and January, 1876, $4 613.46, or about 45 per cent. of the total for the year, were received. In the month of October, 1875, only $295 came in; while in the next month, November, $1 921.10 were received; whereas in November, 1876, only $412.50 were received (or $1,500 less than in the same month of 1875), while in the first 20 days of December, 1876, the receipts were $2 437,43. The mere fact of a *balance* in the treasury at any given date, will not of itself, afford sufficient data upon which to base the disposition of the several expenditures; an analysis of the items of receipts and expenditures will be necessary to determine how much might fairly be appropriated for expenses, beyond the ordinary annual expenditures.

In 1876, the leading items of expenses were:

Secretary and clerks		$3 000 00
Transactions		2 613 00
Rent, fuel and light		1 884 00
Stationery and printing	$537	
Postage	260	
		797 00
Reporting Proceedings		369 00
Total		$8 663 00

These cover about 95 per cent. of all expenses for the fiscal year ending October 31st, 1876.

The leading receipts for the same year came from the following sources:

Entrance fees	$1 670 00
Members' annual dues	7 014 00
Annual interest of funds	630 00
Advertisements	597 00
	$9 911 00

The total amount received was $10 433.39 (including balance, $281.75, at end of the previous year, and $150 Fellowship subscription).

At the end of the fiscal year of 1876, there was an apparent balance of $1 274.77; but a few days after the close of the fiscal year, a number of bills which had to be paid, amounting to some hundreds of dollars, came in.

It may be, we think, safely assumed, that the receipts for the present fiscal year will at least equal those of last year; so that if the receipts should be, in round numbers $10 000, and the usual expenses, say $9 000, there would be between $1 500 and $2 000 (including the actual available balance from 1876), applicable to the Library, or such other purposes as the Society might deem proper.

It may be worth considering, whether or not it is advisable to create and maintain *a reserve fund*, to aid in securing more commodious, permanent quarters.

For convenient reference, we have summed up the receipts in 1876, during each month, as follows:

November, 1875*		$1 921 10
December,	"	1 234 37
January,	1876	1 457 99
February,	"	725 80
March,	"	690 55
April,	"	799 57
May,	"	490 03
June,	"	547 50
July,	"	567 10
August,	"	1 107 50
September,	"	596 88
October,	"	295 00
Total,		$10 433 39

In the spring the balance on hand is heaviest, as the monthly expenditures are more equally divided throughout the year than are the monthly receipts.

With the foregoing statement before them, the Board of Direction can judge (as well as can the Library and Finance Committees) approximately, respecting the disposition of the Society's funds for the present fiscal year. An *average* of about $760 per month was expended during the fiscal year of 1876.

We regard it as a fitting time to establish a system, which can be conveniently carried out, regulating appropriations to be made by the Board of Direction.

W. Milnor Roberts, } Members
W. H. Paine, } Finance Com.

* Including $281.75 balance from preceding year.

STATEMENT OF THE

FINANCES OF THE SOCIETY,

PREPARED FROM THE TREASURER'S REPORTS.*

RECEIPTS, 1875–6.

Past Dues from 7 resident Members	$295 00		
" 17 non-resident "	325 00		
" 1 " Associate	10 00		
		$630 00	
Current Dues from 79 resident Members	$1 975 00		
" 3 " Associates	3 660 00		
" 8 " Juniors			
" 233 non-resident Members			
" 11 " Associates	410 00		
" 30 " Juniors			
" 1 " Member, balance	10 55		
" 1 resident Associate, "	5 00		
		$6 060 55	
Half Dues from 3 resident Members	37 50		
" 3 " Juniors	20 00		
" 24 non-resident Members	180 00		
" 9 " Juniors	45 00		
		282 50	
Additional Dues from 2 Associates and 2 Juniors, who became Members		20 00	
Dues for 1876–7 from 1 non-resident Member		15 00	
Sundry overpayments of Dues		7 09	
Entrance Fees from 43 Members	1 290 00		
" 1 Associate	380 00		
" 18 Juniors			
		1 670 00	
" 1 Fellow		150 00	
			8 835 14
Fellowship Fund. Interest on 8 Jersey City Water Loan Bonds, for year ending July 1st, 1876		560 00	
Norman Medal Fund. Interest on New York City Croton Aqueduct Bond, for year ending November 1st, 1875		70 00	
			630 00
Advertisements in Journal		597 00	
Publications		76 00	
Diplomas		13 50	
			686 50
Treasurer's Receipts for year ending October 31st, 1876			$10 151 64
" Balance, November 1st, 1875		$275 63	
" " of Fellowship Fund		6 12	
			281 75
Total			$10 433 39

* Under direction of the Committee on Finance, in compliance with resolution adopted at meeting of the Society, January 3d. Approved by the Board of Direction, February 7th.

PAYMENTS, 1875-6.

Publications.	Printing Journal of the Society.	$2 322 25			
	Engraving	265 50			
	Copyright	5 00			
			$2 592 75		
	Extra Papers		21 00		
	List of Members		94 75		
				$2 708 50	
Reporting at Seventh and Eighth Annual Conventions				415 78	
Stationery.	Ballot Lists	$30 50			
	Circulars	85 25			
	Forms of Application, Bills, Cards, &c.	30 25			
	Notices of Meetings and other Notices	47 25			
			$193 25		
	Blank Books, Envelopes, Paper, &c.		225 42		
				418 67	
Postage				260 61	
Library.	Books, Binding and Cards			62 45	
Rooms.	Rent		$1 600 00		
	Heating		100 00		
	Gas		16 45		
	Janitor		168 00		
	Ice		4 28		
				1 888 73	
Furnishing				98 82	
Insurance				54 01	
Secretary and Clerks				3 000 00	
Norman Medal, Engraving and Case				74 65	
Safe Deposit, Rent				12 00	
Hand Stamps for Treasurer				5 50	
Expressage and Sundries				88 90	
Miscellaneous				5 00	
					$9 093 62
In Secretary's hands for Office Expenses					65 00
Treasurer's Payments for year ending October 31st, 1876					$9 158 62
" Balance, November 1st, 1876					1 274 77

ASSETS AND RESOURCES, NOVEMBER 1ST, 1876.

Furniture, Library and Transactions on hand, (Secretary's estimate).			$9 000 00	
McAlpine Library (insured for)			2 000 00	
				$11 000 00
Fellowship Fund: 8 Jersey City Water Loan (7%) Bonds, par value $8 000—cost	$8 250 00			
Accrued Interest, from July 1st		186 67		
1 U. S. Registered (5-20, 6% gold) Bond, par value $500—cost	379 38			
Accrued Interest from November 1st, 1875, $30 Gold—say		31 50		
			9 047 55	

Brought over		$9 047 55	$11 000 00
Norman Medal Fund: 1 New York Croton Aqueduct (7%) Bond	$1 000 00		
Accrued Interest from May 1st, 1876	35 00		
		1 035 00	
Deposit in Seaman's Savings Bank for Savings, (January 1st, 1877		821 28	
New York Central Railroad Stock: 5 shares—cost		536 25	
Treasurer's Balance, November 1st, 1876	$1 274 77		
In Secretary's hands for office expenses	65 00		
		1 339 77	
			$12 779 85
Members' past dues		$2 945 00	
" current dues (payable to November 1st)		8 115 00	
			$11 060 00
Total			$34 839 85

The value of dies for the Norman Medal, and dividends on the New York Central Railroad stock accrued, since April 2d, 1868, are not included.

RECEIPTS AND PAYMENTS FOR QUARTER ENDING JANUARY 31ST, 1877.

	Receipts.		Payments.	
In November	$412 50	.....	$1 131 48	
" December	2 453 24	.....	634 91	
" January	1 602 62	.....	262 00	
	$4 468 36	.....	$2 028 39	
Excess of Receipts				$2 439 97
Balance at Beginning of Quarter				1 274 97
Balance at end of Quarter				$3 714 94

NOTES AND MEMORANDA.

SELECTIONS FROM CORRESPONDENCE.

Mount Washington Railway.—During the past season, the Secretary, at request of foreign engineers, sought information in regard to the construction and operation of this railway.

Mr. Charles W. Copeland wrote: The length of this railway is about 3 miles; the total rise from the lower station to Mount Washington House, on the summit is 3 625 feet; and the steepest grade is 1 980 feet to the mile, about 1 in 3, but averaging through the entire course, 1 in 4.

The road bed is constructed with special reference to safety and durability, of heavy timber, clamped to the rocks of the mountain slope, and braced and secured in the strongest manner.

The track is of the usual gauge, with side rails of the usual pattern, and a central safety rail, constructed of two parallel bars of angle iron, with cross bolts of 1½ inch-round iron, at intervals of about 4 inches; between these bolts play the cogs of a central wheel of the locomotive.

In addition to ordinary brakes, the atmospheric brakes, instantaneous in their action, are in use, and, following and dropping into the notch rim of the driving-wheel, is a firm iron support which would effectually prevent the descent of a train in case of injury to the machinery. Rollers under the angle iron prevent jumping or slipping from the track.

With these arrangements for safety, the passenger need feel no alarm or apprehension of danger, the trip being as safe as ordinary rail transit, no accident having occurred in the seven years the road has been in operation, nor damage of a penny to life, limb, or material, during the time of construction, or since its operation as a line of travel.

The locomotive is of novel construction, being made with special reference to the steep inclination of the road, and when standing upon the level track, appears sadly out of balance. Safety and power are attained in the construction, at the expense of speed which is not sought. The locomotive is always below the train, pushing the coach upward as it ascends, and preceding it in the return down the slope. The cars have seats hung at an angle, facing toward the base.

Mr. Copeland also submits these notes ;

The road was built at first with strap rails, but as they were continually breaking, they were taken up, and a T rail weighing 30 pounds to the yard, put down instead. The centre or cog rail is made of 3 inch-angle iron, with pins made of the best Pembroke iron, 4 inches long, 1½ inches in diameter, and 4 inches apart, riveted between them. This cog rail is nothing but an iron ladder bolted to the road bed, into which a gear wheel on the driving axle of the engine works; the cog rail weighs 66 pounds to the yard.

The road was about 3 miles long, but this spring, it was extended down ½ mile more to connect with Boston, Concord & Maine R. R., which now runs to the base of the mountains. There are some pretty sharp curves on it ; I forget the degree of curvature, at all events we run about as short curves as on ordinary roads. There is no switching apparatus as none can be used with centre cog rail, but there are turn-tables.

The original engines had only one pair of cylinders 10 × 16 inches, and all the power was applied to one axle, but this has been improved by using 4 cylinders 8 × 12 inches, and dividing the power between the two driving axles. The crank shaft on the engine is geared to the driving axle in a ratio that the piston makes 5½ strokes to 1 of the driving axle.

Air is used in the cylinders when the train is coming down ; gravity tends to force the train down hill, moves the pistons, and the engineer lets the air out of the cylinders as fast as he wants to run ; there are other brakes besides.

The engine backs down the hill with the car above it. At first, upright boilers were used, but these have been abandoned for horizontal ones, set at an angle that will be level on an average grade. The engines weigh about 12 tons, the cars seat about 50 persons, and weigh about 3 tons. Only one car to an engine is run, but sometimes 80 persons are carried to a car—50 however are enough.

There is not much grading to the road, as the mountain is about all stone. Most of the low places are spanned by trestle work ; that over "Jacob's Ladder" is 27 feet high. The grade varies with the mountain up and down, although the least grade is a rise of 1 in 8.

The original capital was $110 000, but it took all that to build the road ; since, all the earnings of the road have been put into it, in the shape of rolling stock and improvements, till it now has cost over $200 000. The road is not in debt, but has never paid a dividend.

7 000 passengers were carried last year, at a fare up and back of $4. There are 5 engines and 5 cars, also 2 platform cars ; sometimes not more than 10 passengers are carried in a day, and sometimes 200, depending on the weather. It is only a pleasure road, so freight is not carried, although a large hotel has been built on the summit, all of which was carried up over the road.

The receipts are about $24 000 per year, half or more of which, it costs to run the road; it is only run for summer travel—say three months in the year.

Cog railroads were first used in England ; there is one running into Madison, Indiana, one mile long, with a grade of 500 feet ; it has been in operation since 1847, and always been run during summer travel, since the road was opened.

The road up Mount Rhiga, Switzerland, was built from this. Engineers were sent over who got leave and made drawings of this road and its engines.

Mr. Francis Collingwood writes : Having been requested to make such memoranda as he could, respecting the construction and operation of this road, during a recent visit to the White Mountains, the writer would present the following brief and necessarily somewhat imperfect description written from notes made hurriedly on the spot.

The inception of the work was due to Mr. Sylvester Marsh, of Littleton, N. H., who, after much opposition succeeded in building the first road—beginning April, 1866, and completing it in July, 1869. The first track was laid with the outer rails of light, flat iron. The locomotives also were imperfect, the boiler being vertical and filled by the use of a funnel, and having too small a steam space for the service required.

The present superintendent, Mr. Walter Aikin, of Franklin, N. H., has been in charge several years, and has entirely changed the character of the road and rolling stock, so that it is now in efficient working order, and has almost entirely superseded other modes of ascending the mountain.

The road is in two sections, one of 2½ miles length, reaching from Fabyan's (the junction of the "Portland & Ogdensburg"—and the

"Boston, Concord, Montreal & White Mountains" railroads), to "Base Station." This portion has a maximum grade of 296 feet per mile, and is run by traction engines with ordinary cars.

The portion ascending the mountain, and hereafter exclusively considered, has a length of 3⅓ miles. Its maximum grade (at a point called Jacob's ladder, ending at 1 mile from and 800 feet below the summit), is 1980 feet per mile; its minimum grade is 660 feet, and the average 1 300 feet per mile. The vertical curves joining the various grades are quite sharp—but their radii were not learned. There are nine lateral curves, varying from 497 feet to 945 feet radius.

Comparatively little grading was done; low trestling, strongly braced, with bents about 12 feet apart, being used by preference. The Superintendent says, however, that he should change this, were he to reconstruct the road.

Where there is no trestle, heavy cross bearers of timber are bedded against rocks or into the soil, at about 12 feet apart. On these, are bolted longitudinal stringers, 8×12 inches. On these again, are placed sawed cross-ties, originally 4 feet, and since made 2 feet apart. Last of all, are placed a set of longitudinal stringers on top of the cross-ties. The outer ones are 4×7 inches, fastened by bolts reaching through the cross-ties and the lower stringer, every 2 to 4 feet. They support the outer rails, which are light iron rails, 30 pounds to the yard, without fish-plates but with joint-plates. They serve simply to support the car and engine. The middle stringer rests upon and is bolted to the cross-ties. It is 4×8 inches, and supports the central cog-rail. All the bolts, as nearly as could be seen, were screw bolts.

The cog-rail, which is the peculiar feature of this road, weighs 66 pounds, and cost $6 per yard delivered at the base of the mountain. It is made in 12 feet lengths of two pieces of 3×3×⅜ inch-angle iron, placed 4 inches apart and joined by 1½ inch-diameter round pins, placed 4 inches apart, centre to centre, and firmly riveted to the vertical flanges. The rail is, therefore, 10¾ inches wide, and projects 1⅜ inches on each side beyond the stringer to which it is fastened. The reason for this will be seen hereafter. The lateral flanges were pierced for bolts at every 18 inches of length, but bolts were only used at every 3 feet of each angle iron. The pins are made of best Pembroke iron.

The gauge of the track is 4 feet 7½ inches, owing to a fancy of the projector that he must have a *close* gauge. The original cost of the 3⅓ miles of road, with equipment, was about $150 000; but this has since been increased by expenditures from earnings, to $210 000. There are four water tanks at various points, supplied by springs in the vicinity; a turn-table and small engine-house on the summit, and some cheap buildings at the base.

Each train consists of an engine and one car. The first locomotives built, having an upright boiler and but two steam cylinders, weighed 6½ tons each. The latest, designed by Mr. Aikin and built in 1875 at the Manchester Locomotive Works, N. H., have 4 cylinders, a rigid wheel base (the length I did not learn), and weigh 12 tons each. They consume ½ cord of wood each, per round trip. The cars measure 8×30 feet, inside measure, seat 50 persons, and weigh 3 tons each. There is no special arrangement of seats, as in the cars used on the Pittsburgh and other inclined railways. The boiler of the latter engine is of the ordinary locomotive type, except that the steam-drum is at the centre of length of the horizontal shell, instead of at one end. The shell is about 9 feet long (diameter I did not get), and inclined to the frame sufficiently to make it horizontal when the engine is on the average grade. On the *level*, the engine looks as though it had been in collision with another. As stated, each engine has 4 cylinders, 8×12 inches, each pair working on an independent crank shaft, geared respectively into gear-wheels on the forward and rear axles of the engine. The valves are ordinary slide valves, worked from eccentrics on the crank shafts, and cutting off at three-fourths stroke.

In addition to the steam and exhaust pipes, an air supply pipe is carried from each valve chest into the cab, and provided with suitable cocks under the control of the engineer. He is by this means enabled, in going down hill, to shut off steam entirely, and run the train down against the air-pressure in the cylinders, the amount of compression being under perfect control. While thus working and discharging compressed air, the condensation of moisture caused by the rapid expansion of the jet, gives it every appearance of a discharge of steam. After many experiments, Mr. Aikin arrived at the following combination of gears: The pins in the rail, Pembroke iron; the central cog-wheels (one on each axle of the engine, and one on the upper axle of the cars), of best chilled car-wheel iron, 26 inches exterior diameter. At the roots of the teeth, the wheel is 4 inches thick, and at the ends, 3½ inches; this allows for lateral play, curves, &c.

The gear wheels (two on each engine axle, and two on the upper car axle) are 33 inches exterior diameter and 4 inches thick, and made of gun metal. The pinions, two on each crank shaft on both car and engine, of 6 inch diameter, are made of steel. This gives about 5½ revolutions of the engine to 1 of the driving wheels. The speed of ascent and descent of trains is about 2 miles an hour, or at the rate of an easy walk. The engine is always *below* the car, and entirely free from it, the bumpers simply coming in contact. The water-tank and wood-box are on the lower end of the engine, over the lower axle. The baggage crate, a simple platform, runs below all, and is attached to the engine by chains.

The means of stopping the engine are, *first*, a rachet and pawl. The ratchet is about 2 inches in diameter and 5 inches face; it is placed on the upper axle; and the pawl is always playing as the train *ascends*. On going down hill the pawl is held up, but can be instantly dropped by the engineer. In addition to this, are powerful strap brakes on each axle.

For stopping the cars there are—*first*, a ratchet and pawl on the upper axle; *second*, a strap brake on the lower axle, or as in some recent cars, 2 shoe-brakes at each wheel; *third*, an ingenious atmospheric brake, worked by the upper axle of the car, through the gear mentioned and crank axle, corresponding in all respects to those on the engine. One of the brakes is placed on each side of the car, underneath, and consists of a plain cylinder, about 8×12 inches, with piston working in it air-tight, the piston being joined by connecting rod to the corresponding crank on crank shaft. A plain air passage connects the two ends of the shaft, so that the air is pumped alternately from one end to the other. A throttle vaive is placed in this passage, which is under control of the brakeman; and he can, by lessening or increasing the opening, increase or diminish the brake power, at will. As this axle is geared to the central rail, it will be seen that the car is positively held by the brake, and does not depend upon friction.

Mr. Aikin says, they find a great economy to result from a proper *oiling* of the central rail. This they do about once a week, by a can attached to the engine, with a properly adjusted opening.

No views of their most recent engines were obtainable, and the ones exhibited are of the older type. 7000 passengers were carried last year, without an accident, and no passenger has yet been hurt.

A gang of men is kept constantly on the line, and they have a means of descending the line which is both novel and interesting. Each man carries a kind of sled—a flat board, with cross-pieces for the feet and attachments. This slides on the central rail. Near the front end a brake is attached on each side, by a bolt running across the board. The handles of these, reach back to a convenient position for the rider to operate either by lifting or pressing down (according to the style of brake), and the brake takes hold on the under side of the projecting lip of the central rail. It requires large practiee to work these safely, but Mr. Aikin says, an experienced rider will descend the length of the line in 4 minutes, and be able to stop anywhere he desires.

Some details of this road are given in the various guide-books, but they refer rather to the line as first laid, than as at present running.

There are many omissions, and no doubt, some inaccuracies, in this communication, which must be charged to the hurried manner in which the notes were taken, without time for revision and subsequent correction.

* A large photograph of the railway and a train, showing clearly the arrangement of track and centre rail, may be seen at the Society's rooms.

LIST OF NEW BOOKS ON

ENGINEERING AND TECHNOLOGY.

Under this head will be announced new books on these and kindred subjects, which may be professionally useful to members of the Society.

Animals, the Uses of—, in Relation to the Industry of Man. a Course of Lectures. E. Lankester. London. 12mo. *Hardwicke & Bogue.* 4s.

Archæology of Rome. The Aqueducts, traced from their Sources to their Mouths. John H. Parker. London. 8vo, illus. *Murray.* 15s.

—— Discoveries at Ephesus; including the Site and Remains of the Great Temple of Diana. J. T. Wood. London. 8vo. *Longmans.* 63s.

Architectural Sheet-Metal Work, Compendium of—, embracing Rules and Directions for Estimates, Items of Cost, Nomenclature, Tables of Brackets, Modillions. Dentals, Trusses, Stop-Blocks, Frieze-Pieces, &c. Architects' Specifications, Tables of Tin Roofing, Galvanized Iron, &c., &c.; to

which is added, the Exemplar of architectural Sheet-Metal Work, containing Details of the Centennial Buildings, and other important Sheet-Metal Work, Designs, and Prices of architectural Ornaments, as manufactured for the Trade, and a Catalogue of Cornices, Window Caps, Mouldings, &c. A. O. Kittredge. Philadelphia. 8vo. *Baird.* $10.00.

Art, a Manual of the historical Development of— ; pre-historic, ancient, classic, early Christian ; with special Reference to Architecture, Sculpture, Painting and Ornamentation. G. G. Zerffi. London. 8vo. *Hardwicke & Bogue.* 6s.

Azimuth Tables for correcting Compass Courses and Bearings, being the Sun's True Bearings, corresponding to apparent Time at Place. F. Labrosse. 3d ed. London. 8vo. *Van Nostrand, New York.* $6.25.

Birds of Great Britain and Ireland. William Gardiner. New ed., 4 vols. London. 12mo. *Hardwicke & Bogue.* 18s.

Bridges : an elementary Treatise on their Construction and History. F. Jenkin. Reprinted from the Encyclopædia Britannica. Edinburgh. 4to. *Longmans.* (*London.*) 5s.

—— Arch and Suspension Trusses. S. H. Shreve. New York. 8vo, illus. (*Van Nostrand.*) Announcement.

——— Works in Iron Bridge and Roof Structures. E. Matheson, 2d. ed. London. 8vo. *Spons.* (*New York.*) 15s.

Cement, Testing of Portland—J. J. Mann (Minutes of Proceedings, Institution of Civil Engineers). London. 8vo, illus. *Inst. Civil Eng.*

Centi-Meter-Gramme, Illustrations of the—, second System of Units. Prof. Everett. London. 8vo. *Taylor & Francis.* 5s.

Dynamics ; or, theoretical Mechanics in Accordance with the Syllabus of the Science and Art Department. J. T. Bottomley. London. 12mo. *Collins.* 1s. 6d.

Eclectic Engineering Magazine (Van Nostrand's). Vol. 15, July to December inclusive, 1876. New York. 8vo, illus. $3.00.

Fern Paradise. Francis G. Heath. 3d ed. *Hodder & Stoughton.* London. 8vo. 6s.

Firearms, on the Influence of— upon Tactics ; historical and critical Investigations by an Officer of superior Rank in the German Army. Trans. by E. H. Wickham. London. 8vo. *King.* 7s. 6d.

Fishes ; a History of British —. R. Hamilton. 2 vols. London. 12mo. illus. *Hardwicke & Bogue.* 9s.

—— Trout Culture ; a practical Treatise on the Art of spawning, hatching and rearing Trout. Charles C. Capel. London. 12mo. *Hardwicke & Bogue.* 2s. 6d.

Forces ; Application of physical —. Amédée Guillemin. Trans. by Mrs. Lockyer, ed. by J. Norman Lockyer. London. 8vo, illus. *Macmillan* (*New York*). 36s.

Forests and Moisture; or Effects of Forests on Humidity of Climate. John C. Brown. Edinburgh. 8vo. (*Simpkin, London.*) 10s. 6d.

Furniture, Designs and Sketches for —, in the Neo Jacobean and other Styles. Bernard E. Smith. London. Folio, illus. (*Van Nostrand, New York*). $21.00.

Game, the large and small —, of Bengal and the Northwestern Provinces of India. J. H. Baldwin. London. 16mo. *King.* 21s.

Gas; a practical Treatise on the Manufacture and Distribution of Coal —. William Richards. 4to, illus. *Spons.* (*New York.*)

Geological Survey, Memoirs of ——. England and Wales (English Government Publications). Geology of East Somerset and Bristol Coalfields ; or Descriptions of the Rocks comprised in Sheet 19, part of Sheet 35, and adjoining Portions of Sheets 18, 20, and 21 of the (one Inch) geological Survey Map of England. Horace B. Woodward. With Notes by H. W. Bristow, W. A. E. Usher, and J. H. Blake, and Appendix by F, Rutley, on the microscopic Character of the eruptive Rocks, and Lists of Fossils by R. Etheridge. London. 8vo. 18s.

Geology of the northern Part of the English Lake Districts. Quarter-sheet 101 S. E., including Sheets 63, 64, 69, 70, 71, 76, and portions of 54, 55, 56, 57, 62, 65, 68, 73, 74, 75, Cumberland, and 12, 18, 19, Westmoreland, on Scale of 6 inches to Mile. J. Clifton Ward. With Appendix on New Species of Fossils. R. Etheridge. London. 8vo. 9s.

Hydraulics and hydraulic Motors with Theory of the Steam Engine, trans. from Vol. II. of Weisbach's Engineering, by A. Jay DuBois. New York. *Wiley & Sons.* (Announcement.)

———, rural ; a practical Treatise on rural Household Water Supply, giving a full Description of Springs and Wells, Pumps and hydraulic Ram, with Instructions in Cistern Building, Laying of Pipes, &c. W. W. Grier. Philadelphia. 8vo, illus. $0.75.

Iron Manufacture, a concise History of — —, of the American Colonies up to the Revolution, and of Pennsylvania until the present Time. John B. Pearse. Philadelphia. 12mo, illus. *Allen, Lane & Scott.* $2.00.

Library, a Classification and Subject-Index for cataloguing and arranging the Books and Pamphlets of a Library. Melvil Dewey. Boston. 8vo. *Ginn & Heath.* $1.00.

Life, the Puzzle of —, and how it has been put together, a short History of vegetable and animal Life upon the Earth, from the earliest Times, including an Account of pre-historic Man, his Weapons, Toils, and Works. Frederick Waddy. London. 12mo, illus. *Longmans.* 5s.

Magnetic Declination in the United States and other Parts of North America, the secular Change of—. Washington. 4to. *U. S. Coast Survey.*

Mathematics complete : a Science Manual. H. Major. Manchester. 12mo. (*London. Simpkin.*) 2s. 6d.

Masonry, Bricklaying and Plastering, theoretical and practical: the new Guide to — —. Ed. by R. Scott Burn. London. 4to, illus. (*Van Nostrand. New York.*) $21.00.

Mining Engineers, Transactions of the American Institute of — —. Vol. IV. May, 1875, to February 1876. Easton. 8vo, illus.

—— Machinery, a descriptive Treatise on Machinery, Tools, and other Appliances used in Mining. G. G. Andre. (To be completed in 12 monthly Parts.) Part I. London. 4to, illus. *Spons.* (*New York.*) $2.00.

Mineralogy. Text-Book of —. E. S. Dana. New York. *Wiley & Sons,* (Announcement.)

Mineral Statistics for 1875. (Parliamentary Report.) London. 8vo. 2s.

Oils and Water Colors. William Renton. Edinburgh. 12mo. (*Hamilton. London.*) 5s.

Ordnance, Description of naval 3-Inch Breech-Loading Howitzers, with Instructions for their Use and Care. M. Sicard. Washington. 8vo, illus. *Gov. Printing Office.*

Petroleum, the early and later History of —, with authentic Facts in Regard to its Development in western Pennsylvania, and Sketches of the pioneer and prominent Operators, together with the refining Capacity of the United States. J. T. Henry. Philadelphia. 8vo, illus. *Baird.* $4.50.

Price Tables, specially designed for Use in the Iron, Steel, Brass, Copper, Lead, Tin, and Zinc Trades. George Beecroft. 6th ed., rev. and enl. by John O. Butler. Leeds. 12mo. (*London. Simpkin.*) 16s.

Railways. Treatise on the Law of —. William Hodges, 6th ed., by J. M. Lely. London. 8vo. *Sweet.* 38s.

Railway Tires, the Fracture of —. W. W. Beaumont, with Abstract of Discussion (Minutes of Proceedings, Institution of Civil Engineers). London. 8vo, illus. *Inst. Civil Engineers.*

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Roof Trusses, graphical Analysis of — —, for the Use of Engineers, Architects and Builders. Charles E. Greene. Chicago. 8vo, illus. *Engineering News.* $1.25.

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Steam Engine, a practical Treatise on the — —, containing Plans and Arrangements of details for fixed Steam Engines, with Essays on the Principles involved in Design and Construction. Arthur Rigg. (To be completed in 12 monthly parts.) Part I. London. 4to, illus. *Spons.* (*New York.*) $2.00.

Trigonometry, the Elements of plane —. H. N. Wheeler. *Boston.* 12mo. *Ginn & Heath.* $1.25.

Universe (the). F. A. Pouchet. 4th ed. Edinburgh. 8vo. *Blackie.* (*London.*) 12s. 6d.

Vegetable Kingdom, the Effects of Cross and Self-Fertilization in the — —. Charles Darwin. London. 8vo. *Murray.* 12s.

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Proceedings of the American Philosophical Society for promoting Useful Knowledge. Philadelphia. Nos. 93–95, 97.

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Annual Message of President of United States, December 4th, 1876, with Accompanying Documents. Washington.

Congressional Directory, XLIV Congress, 2d Session. Washington.

From J. J. R. Croes, Yonkers, N. Y.:

Department of Public Parks, New York. Reports of the Landscape Architect, and the Civil and Topographical Engineer, on laying out the 23d and 24th Wards, New York.

From M. S. Day, U. S. Navy:

Report of the Trigonometrical Survey of Island of Hokkaido, for 1875. New York.

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Public Libraries in the United States, their History, Condition and Management. Special Report. Parts I. II. Washington.

From C. Douglas Fox, London:

Institution of Civil Engineers; Charter, By-Laws and Regulations; Subjects for Papers, Session 1875–76. (2 numbers.)

From G. H. Frost, Chicago:

Graphical Analysis of Roof Trusses. Charles E. Greene, Chicago.

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39th Annual Report of the Philadelphia, Wilmington & Baltimore R. R. Co. for year ending October 31st, 1876. Philadelphia.

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Department of Public Parks, New York. Specifications, &c., for building an Iron Bridge across Harlem River.

From Albert Hill, New York:

Analysis of Specifications for Steel Cable Wire for East River Suspension Bridge. Albert Hill. New York.

From Institution of Civil Engineers, London:

List of Members. January 1st, 1877.

Excerpts from Minutes of Proceedings. Sessions 1876–7, Part I., as follows:

Fracture of Railway Tires. W.W. Beaumont, with Abstract of Discussion.

The Japan Lights with which the Japan Government has provided the leading Ports. R. H. Brunton ; with Abstract of Discussion.

Permanent Way of Railroads. R. Price Williams ; with Abstract of Discussion.

Testing of Portland Cement. I. J. Mann.

From Capt. W. N. Jeffers, Chief of Bureau of Ordnance, Navy Department, Washington :

Description of naval 3-inch Breech-Loading Howitzers, with Instructions for their Care and Use. Washington.

From North of England Institute of Mining and Mechanical Engineers. Newcastle-on-Tyne, England :

Transactions, September and October. Newcastle-on-Tyne.

From P. H. Philbrick, Iowa City, Ia.:

Catalogue of the State University at Iowa City, for 1873-4, 1875-6. (2 numbers.)

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Treatise on Construction of dredging Machines and their Work. P. P. Panayeff, Moscow (Russian).

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On Rail Joints—from "Engineer." London. (6 copies).

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Act relating to Commissioners of Transportation of State of California, their Powers and Duties. Approved April 3d, 1876. Sacramento. (6 copies.)

Form of Annual Report of Railroad Companies to the Board of Commissioners of Transportation of State of California, for year ending June 30th, 1876. Sacramento. (6 copies.)

From Society of Architects and Engineers of Hanover :

Journal of the Society. Vol. 12. Part IV. (German.)

From the Society of Civil Engineers, Paris :

Papers and Proceedings of the Society. September, October, 1876. Paris (French).

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Exhibits of the Stevens' Institute of Technology at the Centennial Exhibition. Hoboken. (Copies for distribution.)

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Report on the Transportation Route along the Wisconsin and Fox Rivers, in State of Wisconsin. Washington. (Copies for distribution.)

From Miscellaneous Sources :

American Library Journal. September 30th, 1876.

Encyclopaedia Britannica. 9th edition. Vols. I.–V. A to Cle.

Library Table. Vol. II., No. 2. New York.

Prospectus of American Wood Preserving Company. New York, 1870.

Tribune Almanac and political Register for 1877. New York.

ANNOUNCEMENTS.

MEETINGS OF THE SOCIETY for the next three months will be held as follows : *regular* meetings, when ballots for members will be canvassed, and other business done, Wednesday, March 7th, April 4th and May 2d ; and *stated* meetings, for consideration of professional topics and enjoyment of social intercourse, Wednesday, February 21st, March 21st and April 18th—each at 8 o'clock P. M.

MEETINGS OF THE BOARD OF DIRECTION during the same term, for the transaction of regular business, will be held March 7th, April 4th and May 2d, at 3 o'clock P. M.

A *general* meeting of the AMERICAN INSTITUTE OF MINING ENGINEERS will convene Tuesday, February 27th, at 8 o'clock P.M., at the rooms of this Society. One or more sessions will be held on Wednesday, at the Columbia College School of Mines. Wednesday evening will be devoted to a *conversazione* at the rooms of this Society, in which members of both associations will take part. An informal discussion will be had on the advisability and practicability of adopting in this country the metric system of weights and measures.

PAPERS HAVE BEEN RECEIVED for presentation to the Society, since the last announcement, as follows :

Failure of the Railway Bridge at Ashtabula, Ohio.

G. K. Warren. January 18th, 1877.

E. S. Philbrick. February 6th, 1877.

"Levees, as a System of reclaiming low Lands."

Discussion—J. F. Flagg. Feb. 13th, 1877.

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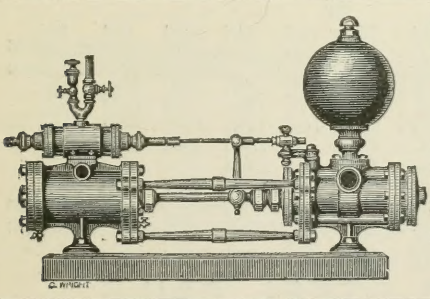

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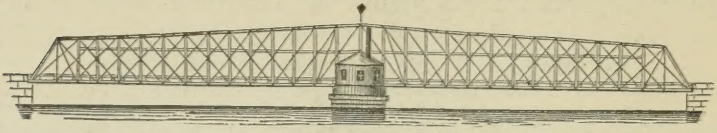

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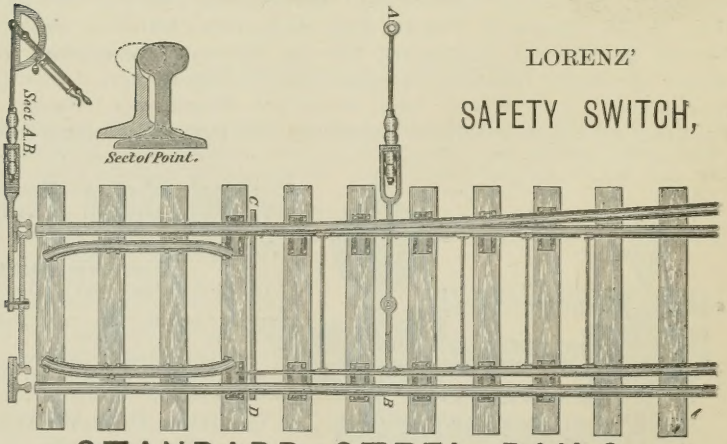

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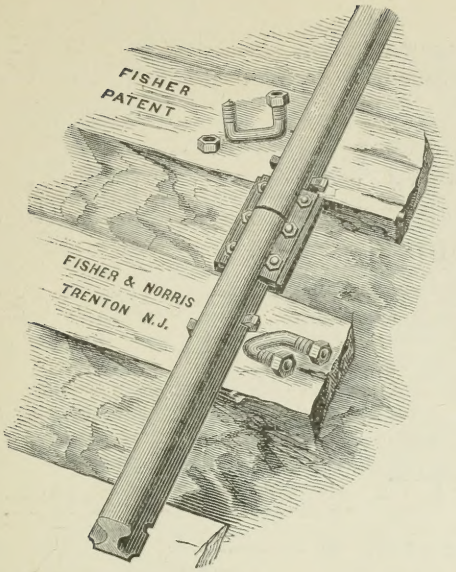


THE "FISHER"

Patent Rail Joint,

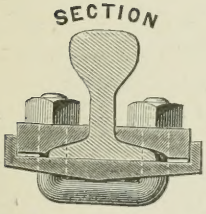
MANUFACTURED BY

FISHER & NORRIS,

Trenton, N. J.

In the "Fisher" system by *vertical* bolts, the ends of contiguous rails are securely fastened between heavy horizontal plates, which enclose the flanges.

Of these bolts, usually in pairs in the ⌊⌋ form, one, two, three or four are employed as desired. From their large diameter (one inch), and acting in the same direction as the load, *no loosening of the nuts* occurs, except that due to internal wear of the plates and rail surfaces. Having the whole area of the base of rail, instead of a narrow bearing under the head, as with common fish bars, this wear is very slight, and may be taken directly up by the nuts. Twice a year, using a four foot wrench, is sufficient for this, and no "stop" or other washers are required or used.



Joints taken from the track of the Boston & Providence R. R., after *thirteen years'* continuous use, show this wear to have been $\frac{3}{64}$th of an inch.

No holes are made in the stem of the rail. The only slotting is for elliptical notches in the edges of the flanges and without perceptible weakening of their strength. Several varieties have been in use on important roads, for from four to thirteen years—either between ties, on one tie, or extending the lower plate over two ties, and in every case have demonstrated that for preservation of rails, smoothness of track, and saving in labor and repairs, the *vertical* system, holding the rail by its broad base instead of under the head, directly by large vertical bolts, is the correct one as opposed to fish bars, which are dependent on horizontal bolts to keep them in place—subject to rapid, unequal wear and cross-strains, and with continual loosening of nuts. All fish bars wear greatest at their middle, and after three or four years' use they will be found so much more worn there than at their ends that a perfect bearing can be no longer obtained by screwing up the nuts, and a rapid destruction of the ends of the rails obtains soon after.

Among the roads which have used these joints in large quantities for a number of years, are the Fitchburg R. R., Boston & Providence R. R., Pennsylvania R. R., Lehigh & Susquehanna R. R., Philadelphia, Wilmington & Baltimore R. R., Cumberland & Pennsylvania R. R., Delaware & Hudson Canal Co., &c.

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